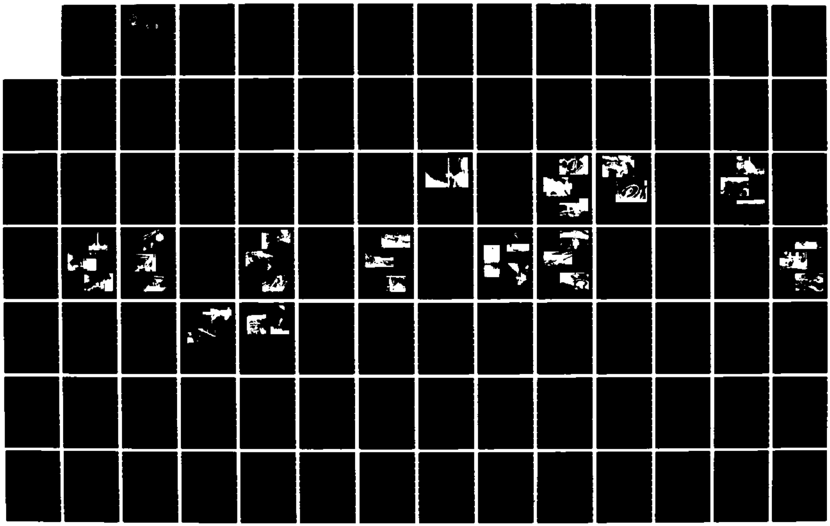
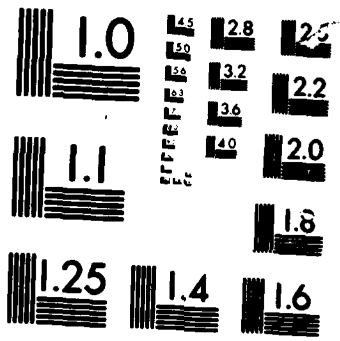
AD-A168 603 INDIAN ISLAND MOORING PROJECT PHASE II COMPLETION 1/2
REPORT(U) TAGGART (ROBERT) INC FAIRFAX VA MAR 84
CHES/NAVFAC-FPO-1-84(2)

UNCLASSIFIED F/G 13/2 NL





MICROCOP

CHART

(2)

[illegible]
PHASE I COMPLETION REPORT

FPO-1-84-[illegible]

MARCH 1984

PREPARED BY

ROBERT TAGGART INCORPORATED
FAIRFAX, VIRGINIA

FOR

OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D. C. 20374

INDIAN ISLAND MOORING PROJECT
PHASE II COMPLETION REPORT

FPO-1-84(2)
MARCH 1984

PREPARED BY

ROBERT TAGGART INCORPORATED
FAIRFAX, VIRGINIA

FOR

OCEAN ENGINEERING AND CONSTRUCTION PROJECT OFFICE
CHESAPEAKE DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
WASHINGTON, D. C. 20374

BLOCK 19 (Con't)

their installation. The components of these three moorings had previously be procured by the Naval Undersea Warfare Engineering Station, Keyport, WA. The tasks involved were expected to be similar to those in the design and installation of the first three moorings at Indian Island which had been installed by CHESNAVFACENGCOM in January and February of 1979. This request was later revised to include the relocation of one of the previously installed moorings which had moved from its installed location during the interim. The 1979 effort was designated as Phase I and the 1983 effort was designated as Phase II.

Design work and project planning on Phase II began immediately. It had been decided to use Class E mooring components for the three new moorings vice the Class C mooring components that had been used in Phase I. However, for the relocation of the one Phase I mooring, the original design and components would be reused except that the old anchors would be replaced with heavier anchors. To supplement the design effort, an inspection was conducted in November 1982 to assess the condition of the Phase I moorings and to obtain some bottom samples for analysis.

In the planning of Phase II Construction Operations, the Army National Guard 144th Transportation Battalion once again was called upon to provide crane barge and tug services. For phase II, Underwater Construction Team Two supplanted the Civil Engineering Laboratory divers used in Phase I and wharfbuilders from Puget Sound Naval shipyard supplanted the riggers from the Public Works Center, San Diego. The Project Execution Plan for this operation was issued by CHESNAVFACENGCOM in July 1983.

The actual construction operations began on 16 August 1983 and the final mooring installation was completed and tested on 3 September 1983. The installed buoys, and the calculated movements of explosives storage barges moored to the buoys, met all of the spacing requirements for distance between barges, and all but one of the requirements for minimum distance to points on shore. The post-installation analysis indicates that the stern of a barge moored to Buoy #3 could swing in an arc that would overlap the 2350-foot radius from the mine shop by 54 feet . The total installation was completed on schedule and within the estimated cost.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A168603

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

3. DISTRIBUTION AVAILABILITY OF REP.
Approved for public release; distribution is unlimited

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

4. PERFORMING ORGANIZATION REPORT NUMBER

5. MONITORING ORGANIZATION REPORT #
FPO-1-84(2)

6a. NAME OF PERFORM. ORG.
Robert Taggart Inc.

6b. OFFICE SYM

7a. NAME OF MONITORING ORGANIZATION
Ocean Engineering
& Construction
Project Office
CHESNAVFACENGCOM

6c. ADDRESS (City, State, and Zip Code)
Fairfax, VA

7b. ADDRESS (City, State, and Zip)
BLDG. 212, Washington Navy Yard
Washington, D.C. 20374-2121

8a. NAME OF FUNDING ORG.

8b. OFFICE SYM

9. PROCUREMENT INSTRUMENT INDENT #

8c. ADDRESS (City, State & Zip)

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT #	PROJECT #	TASK #	WORK UNIT ACCESS #

11. TITLE (Including Security Classification)
Indian Island Mooring Project Phase II Completion Report

12. PERSONAL AUTHOR(S)

13a. TYPE OF REPORT

13b. TIME COVERED
FROM TO

14. DATE OF REP. (YYMMDD)
84-03

15. PAGES
99

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if nec.)
Mooring systems, Indian Island, WA

19. ABSTRACT (Continue on reverse if necessary & identify by block number)
In April 1982, the Commanding Officer, Western Division, Naval Facilities Engineering Command (WESTNAVFACNEGCOM) requested the Commanding Offic r Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM) to design three new moorings at Indian Island, WA, and to plan & manage (Con't)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
SAME AS RPT.

21. ABSTRACT SECURITY CLASSIFICATION

22a. NAME OF RESPONSIBLE INDIVIDUAL
Jacqueline B. Riley

22b. TELEPHONE
202-433-3881

22c. OFFICE SYMBOL

DD FORM 1473, 84MAR

SECURITY CLASSIFICATION OF THIS PAGE

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

LIST OF FIGURES

LIST OF FIGURES (Cont'd.)

LIST OF FIGURES (Cont'd.)

1.0 EXECUTIVE SUMMARY

In April 1982, the Commanding Officer, Western Division, Naval Facilities Engineering Command (WESTNAVFACENGCOM) requested the Commanding Officer, Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM) to design three new moorings at Indian Island, WA, and to plan and manage their installation. The components of these three moorings had previously been procured by the Naval Undersea Warfare Engineering Station, Keyport, WA. The tasks involved were expected to be similar to those in the design and installation of the first three moorings at Indian Island which had been installed by CHENSAVFACENGCOM in January and February 1979. This request was later revised to include the relocation of one of the previously installed moorings which had moved from its installed location during the interim. The 1979 effort was designated as Phase I and the 1983 effort was designated as Phase II.

Design work and project planning on Phase II began immediately. It had been decided to use Class E mooring components for the three new moorings vice the Class C mooring components that had been used in Phase I. However, for the relocation of the one Phase I mooring, the original design and components would be reused except that the old anchors would be replaced with heavier anchors. To supplement the design effort, an inspection was conducted in November 1982 to assess the condition of the Phase I moorings and to obtain some bottom samples for analysis.

In the planning of Phase II Construction Operations, the Army National Guard 144th Transportation Battalion once again was called upon to provide crane barge and tug services. For Phase II, Underwater Construction Team Two supplanted the Civil Engineering Laboratory divers used in Phase I and wharfbuilders from Puget Sound Naval Shipyard supplanted the riggers from the Public Works Center, San Diego. The Project Execution Plan for this operation was issued by CHESNAVFACENGCOM in July 1983.

The actual construction operations began on 16 August 1983 and the final mooring installation was completed and tested on 3 September 1983. The installed buoys, and the calculated movements of explosives storage barges moored to the buoys, met all of the spacing requirements for distance between barges, and all but one of the requirements for minimum distance to

points on shore. The post-installation analysis indicates that the stern of a barge moored to Buoy #3 could swing in an arc that would overlap the 2350-foot radius from the mine shop by 54 feet (see Section 5.0). The total installation was completed on schedule and within the estimated cost.

2.0 PROJECT DESCRIPTION

Phase II of the Indian Island Mooring Project is the continuation and completion of an effort initiated in June 1978 to provide a set of six fleet moorings off the west coast of Indian Island in Puget Sound. The purpose of this mooring facility is to provide a means of securing ammunition storage barges while the ships from which ammunition has been offloaded are undergoing repair or overhaul at the Puget Sound Naval Shipyard (PSNS). The facility is operated by the Naval Undersea Warfare Engineering Station (NUWES) in Keyport, Washington.

BACKGROUND

The Indian Island Project was initiated when the Officer-in-Charge of Construction, Naval Facilities Engineering Command, TRIDENT (OICC, TRIDENT) was tasked to provide the first three of the six moorings. In June 1978, the Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM, FPO-1) was requested to perform a design review of the installation. After studying the problem and evaluating the available assets, a construction team was assembled under the management of CHESNAVFACENGCOM comprising a dive team from the Navy Civil Engineering Laboratory, construction vessels and operating personnel from the State of Washington National Guard, and mooring rigging personnel from the Public Works Center, San Diego. This team completed the installation of the first three moorings, numbers 1, 2, and 6, during January and February 1979 as described in the project completion report [1].*

Because of the unusual site characteristics and the critical nature of the function of these moorings, it was extremely important that they be precisely positioned and that the movement of YC and YFN barges moored to them be restricted. The watch circles through which the barges could swing must not permit interaction between barges, barge groundings, or allow the barges to swing too close to shore installations. For this reason, modified Class E moorings were used wherein the riser chain between the ground ring and the buoy was shortened to pretension the three ground legs and thus restrict the movement of the buoy under applied mooring loads.

---

*Numbers in brackets designate references listed at the end of this report.

In April 1982, CHESNAVFACENGCOM was tasked [2] to design and install the remaining three moorings. The general area of the mooring location as it relates to Admiralty Inlet and Indian Island in Puget Sound is shown in Figure 2-1.

INSPECTION AND ANALYSIS OF EXISTING MOORINGS

Another responsibility of CHESNAVFACENGCOM is the Fleet Mooring Maintenance Program which calls for conducting periodic inspections of all fleet moorings worldwide. As a part of this program, and in view of the requirement to design and install the remaining three moorings, an inspection of the first three Indian Island moorings was scheduled for November 1982.

This inspection was actually carried out by divers of Explosive Ordnance Disposal Group One, Detachment Keyport under CHESNAVFACENGCOM tasking. The inspection report [3] concludes with the following comments and recommendations:

- o The conditions of the buoys, chain, and chain hardware indicate no serious material deficiencies. No corrective action is currently required or recommended.
- o The pretension of the ground legs of moorings numbers 2 and 6 has been maintained during four years of mooring use. As a result, these moorings should meet the strict placement and watch circle requirements particular to this site. No corrective action is required or recommended.
- o Mooring number 1 has moved from its desired location, is no longer properly pretensioned, and can no longer meet the strict placement and watch circle requirements particular to this site. Recommend the cause of the failure be investigated with the possibility of a redesign and reinstallation.

Mooring numbers 2 and 6, as noted above, were in satsifactory condition and were within the prescribed locations. The location of mooring number 1, however, was unsatisfactory. The latter mooring had been displaced about 140 feet west of its installed position. Analysis indicated that two mooring anchors had been dragged such that the minimum distance between the small craft pier and a moored barge was 100 feet less than that required.

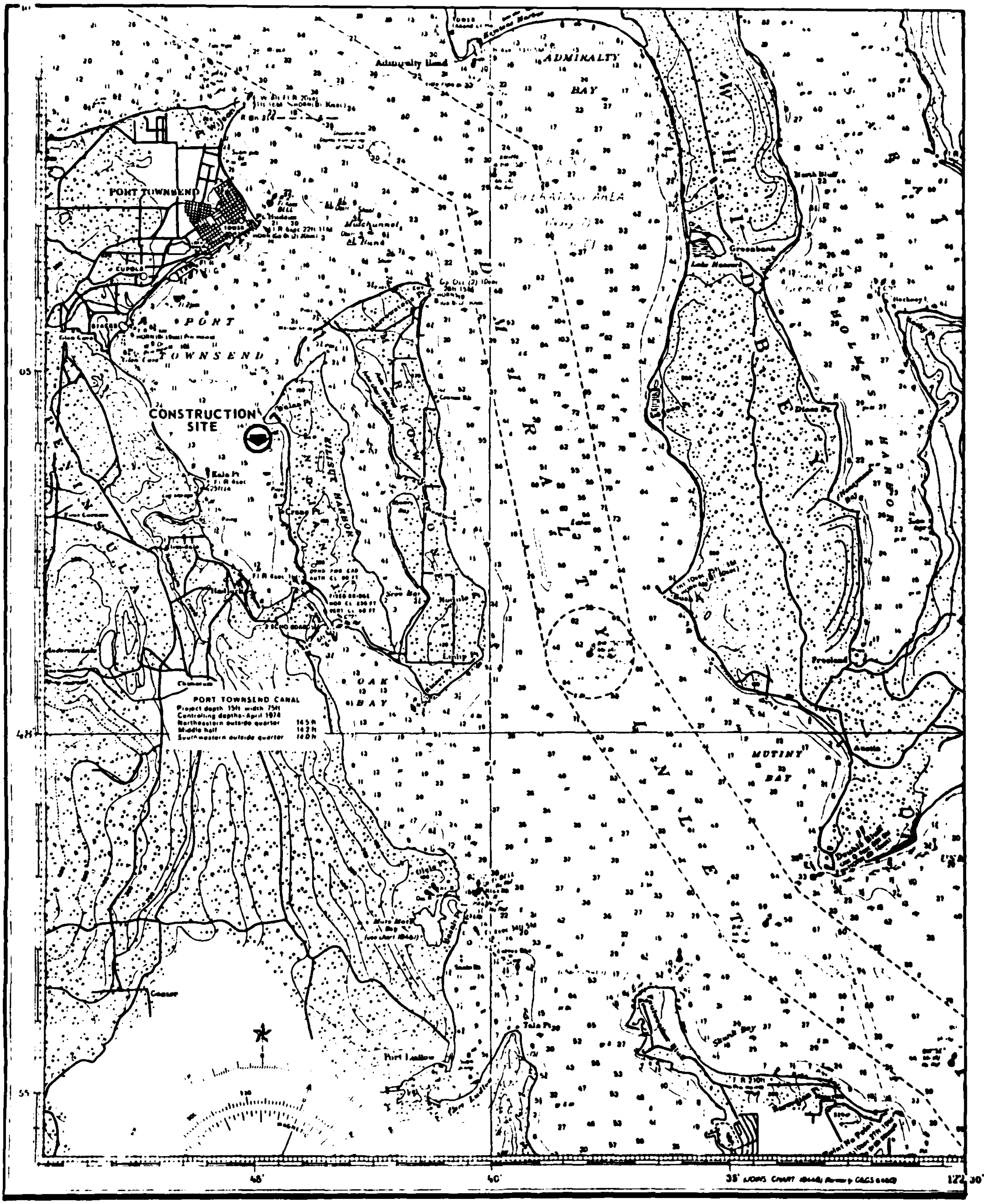


CHART OF ADMIRALTY INLET, PUGET SOUND SHOWING PROJECT AREA

FIGURE 2-1

Furthermore, the watch circle of a moored barge around the relocated mooring would have a negative effect on the locations of the three additional moorings to be installed.

It was concluded that buoy number 1 had been displaced as a result of a larger vessel tying up to it and applying a load greater than that for which the mooring was designed. As a result of this dislocation, the project plan was amended to include the removal of mooring number 1, redesign to withstand greater loads, effecting any necessary repairs to the mooring itself, and reinstallation of that mooring.

Five of the six planned mooring locations were in water of relatively constant depth between 75 and 90 feet; additionally, a detailed sub-bottom acoustic survey had been conducted prior to the 1978 construction operations. Mooring number 3, however would be anchored in an area where the bottom shoaled rapidly toward shore and the sub-bottom characteristics could have an influence on both the exact location of the anchors and on the design of the mooring. During the inspection of the existing moorings, it was decided to obtain data on the bottom characteristics in this particular area where the depth varied from 75 down to 15 feet.

A simple probe, comprising a 12-foot, #3 reinforcement bar with the lower end pointed and the upper three feet bent to a 90° angle, was used for this bottom examination. The bar was marked at one-foot intervals; a diver pushed it into the bottom and judged the effort required to reach different degrees of penetration.

In an area around mooring number 1, where the bottom was known to be soft mud, very little effort was required to push in the entire probe length plus the length of the diver's arm. At five locations in the prospective shallow water anchor location, in water depths between 20 and 50 feet, the probe could only be pushed two or three inches into the bottom. The very firm resistance encountered, and analysis of a sample obtained from just below the soft mud overlay, led to the conclusion that in this area the bottom essentially consisted of firm sand with a shallow mud overlay.

The bottom probe report [4] gives a more detailed account of this aspect of the 1982 Indian Island mooring inspection.

PLANNED LOCATION OF MOORINGS

Because of the dislocation of mooring number 1, it was considered

desirable to remove the existing mooring, substitute anchors with stabilizers, and then replant the mooring. It was recognized that this particular mooring, being closest to the shipping lanes, was most likely to be subjected to unauthorized loadings applied by other marine traffic during bad weather conditions. As a result, mooring number 1 would be redesigned and located so that it could withstand a greater horizontal loading without exceeding the watch circle limits established for the other moorings.

Since mooring numbers 2 and 6 were satisfactorily implanted, new compatible locations were established for mooring numbers 1, 3, 4, and 5 which would meet the prescribed criteria. These are shown in Figure 2-2, which is a chart of the project area between Indian Island and Quimper Peninsula.

The scale of this chart is 1:20,000. It gives both a geographical grid showing latitude and longitude and the Washington State Lambert North Zone Grid which is in feet. The latter grid is used as a reference for all coordinates presented in this report.

The planned buoy positions are designated by numbers in circles. Additionally there are shown two stars in circles which designate the locations of bench marks for transits that were used for sighting in and triangulating buoy positions and the locations of working vessels during the course of the project. Originally, it was intended to use a third bench mark at Kala Point on the mainland but, as discussed later, use of this bench mark was discontinued.

Due to navigational errors, the moorings installed in 1978 were installed approximately 100 feet west of their planned location as illustrated in Figure 2-3. The large circles indicate the planned and actual dislocation of the mooring buoys under a 12 kip load test. In working out the mooring spacings for the reinstallation of mooring number 1 and the locations for mooring numbers 3, 4, and 5, this installation inaccuracy was taken into account and mooring numbers 2 and 6 were to remain where they had been installed in 1978.

The locations of the six Indian Island moorings were still intended to meet the original criteria established in 1978. The moorings were to be located to maintain a required separation of the ammunition barges from each other and specified minimum distances from various shore installations. These distances were a function of the anticipated weight of explosives to

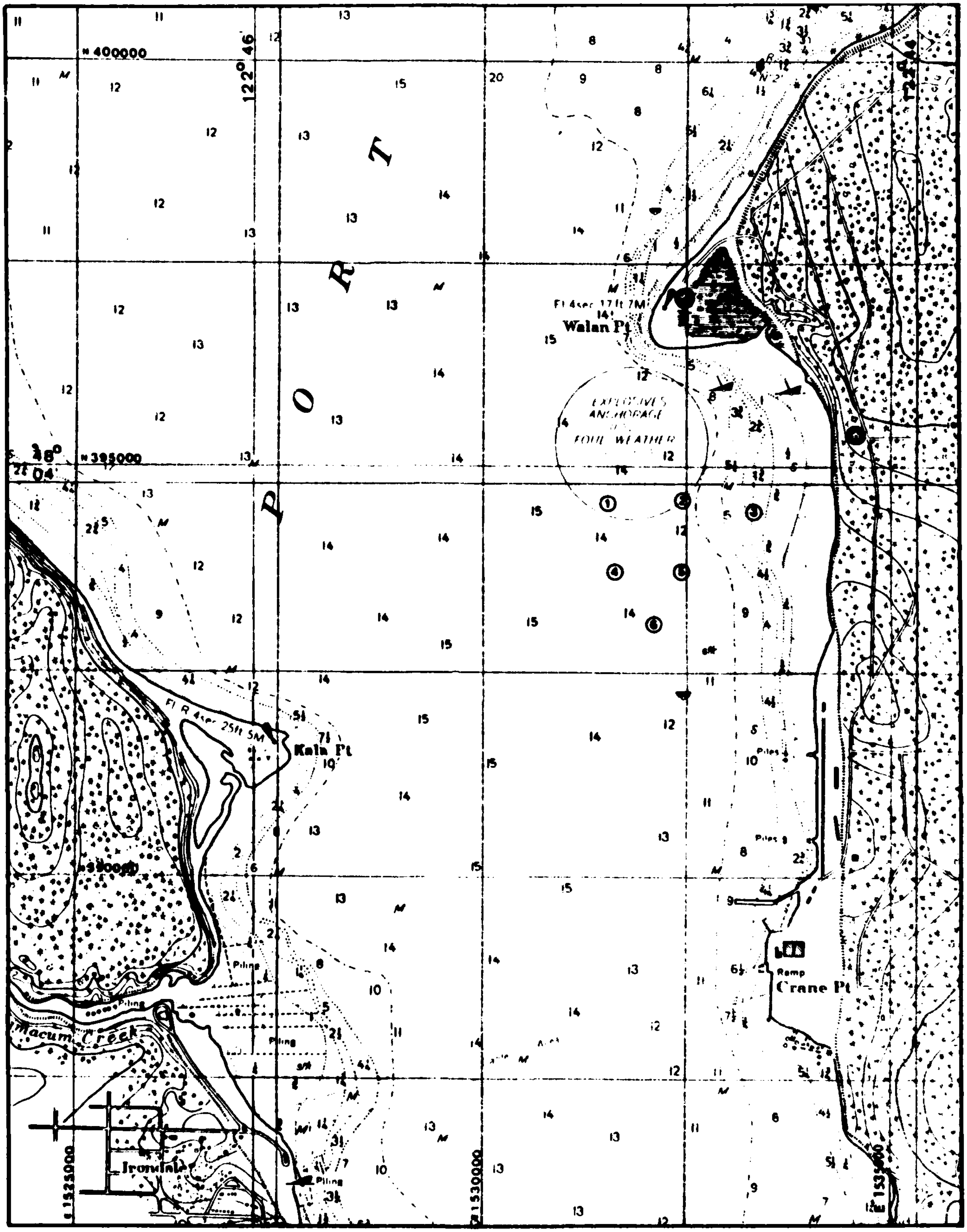
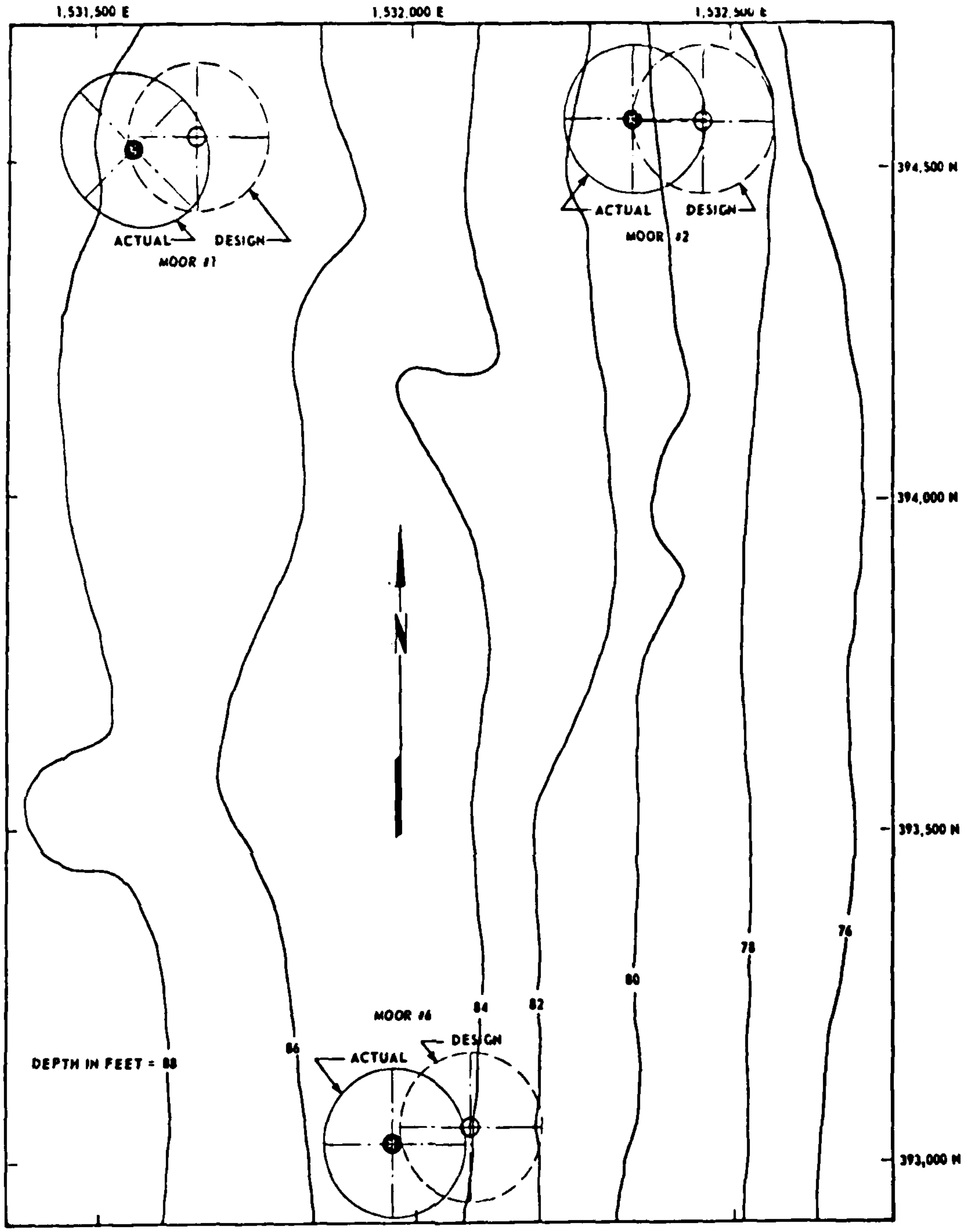


CHART OF PROJECT AREA: WASHINGTON STATE COORDINATES IN GREEN; BUOY LOCATIONS IN CIRCLES; WALAN AND CLIFF SITE POINTS IN STARS

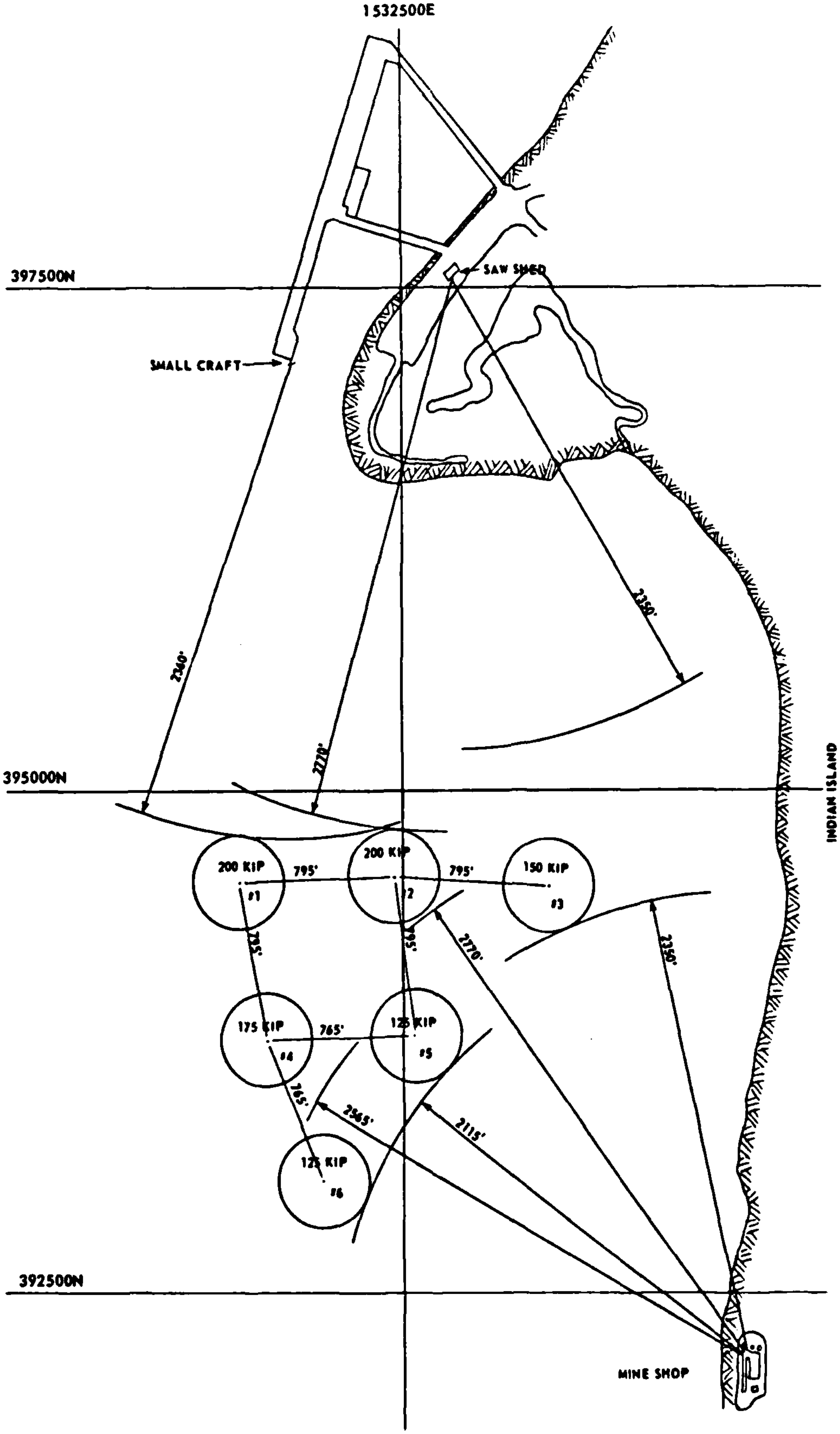
FIGURE 2-2



INSTALLATION LOCATION OF MOORINGS IN 1978

FIGURE 2-3

be carried on each of the moored barges. The required separations, and Explosive Safety Quantity Distances (ESQD), are depicted in Figure 2-4. In this figure it can be seen that the Phase I moorings were to be packed as closely as possible, allowing for placement errors, bridle length, barge length, and watch circle. Since the Phase I installation placed buoy numbers 1, 2, and 6 about 100 feet west of these planned locations, there was more room to place the Phase II moorings. Although the original tolerances and watch circles were used as target values, they were not as critical as in Phase I.



PLANNED PHASE I MOORING LOCATIONS ARRANGED TO MEET BARGE SEPARATION CRITERIA AND DISTANCES FROM SHORE INSTALLATIONS

FIGURE 2-4

Using the actual locations of mooring buoy number 2 and mooring buoy number 6, a new mooring location plan was worked out to provide the prescribed distances between barges and distances from fixed shore points. These planned locations, including the actual locations of buoys numbers 2 and 6, in Washington State Lambert North Zone Coordinates, are tabulated below.

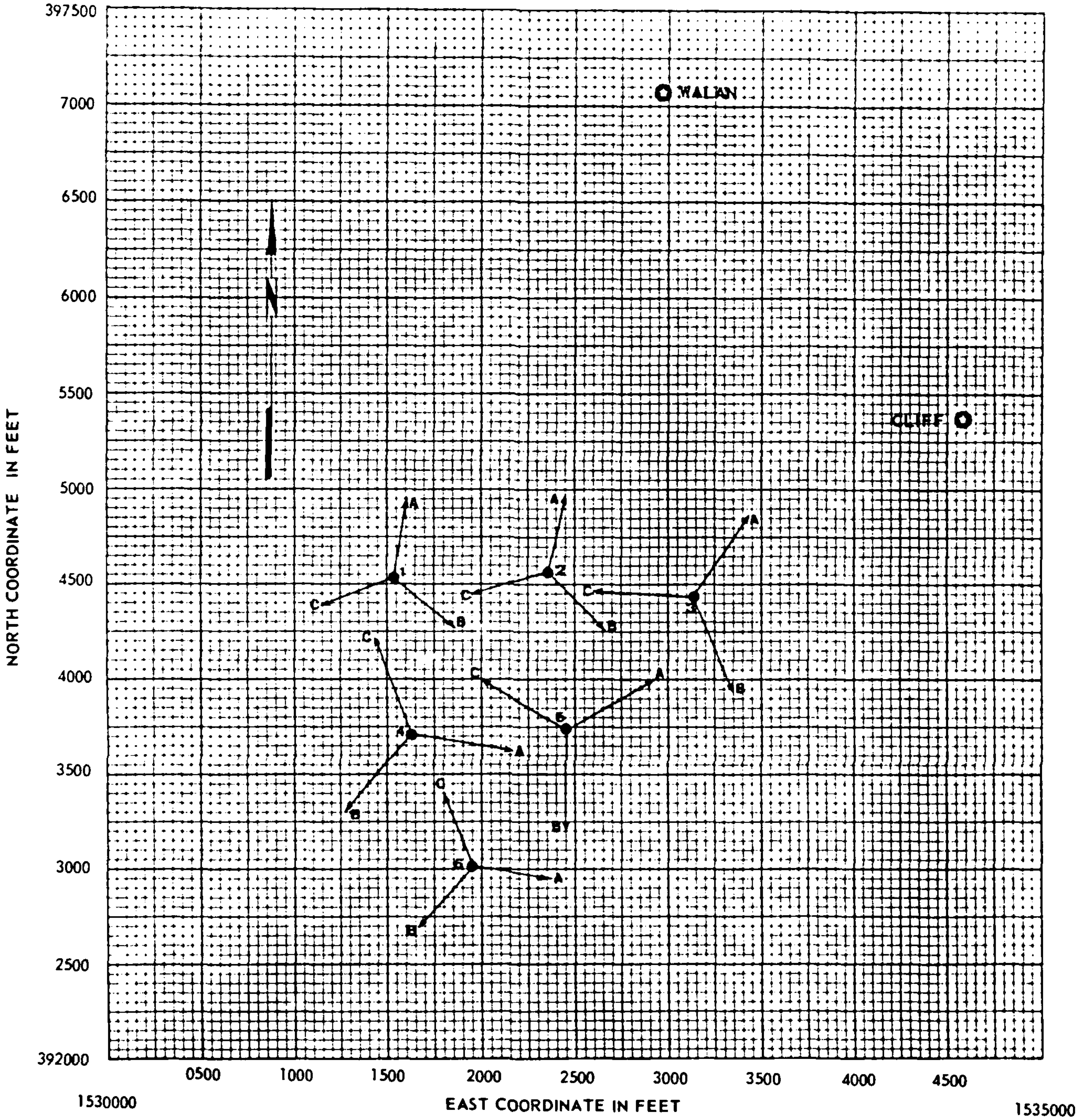
Mooring Number	Phase II Planned Coordinates in Feet North	Phase II Planned Coordinates in Feet East	MLLW Water Depth in Feet
1	394545	1531545	87.5
2	394572	1532350	80.0
3	394432	1533133	51.0
4	393722	1531633	87.0
5	393740	1532456	79.0
6	393026	1531963	85.0

These buoy locations are shown graphically in Figure 2-5. The centerpoint separations between buoys in feet are compared in the table below with the minimum separations either shown in Figure 2-4 or otherwise specified [5].

Buoy Number	to	Buoy Number	Minimum in Feet	Planned in Feet
1		2	795	805
1		4	795	828
2		3	795	795
2		5	795	839
3		5	735	968
4		5	765	823
4		6	765	770
5		6	700	868

The planned separations are equal to or greater than the specified minima in all cases.

Also shown in Figure 2-5 are the horizontal projections of the ground legs and the anchor positions for the six buoys as well as the transit sight points used for all 1983 Phase II construction operations. For the purposes of this report, and to follow the Fleet Mooring Inspection Program notation, the three legs for each mooring will be designated alphabetically clockwise with *A* being the first leg east of north, *B* the second in a clockwise direction, and *C* the third. These designations do not necessarily indicate the



PLANNED POSITIONS OF BUOYS, ANCHORS, AND SIGHT POINTS
IN WASHINGTON STATE LAMBERT NORTH ZONE COORDINATES

FIGURE 2-5

order of implantation which will be noted herein as *first, second,* and *third* leg implanted.

The Washington State Lambert North Zone Coordinates for the "Walan" and "Cliff" transit sight points on Indian Island and the planned or actual anchor locations for the six mooring buoys are tabulated below.

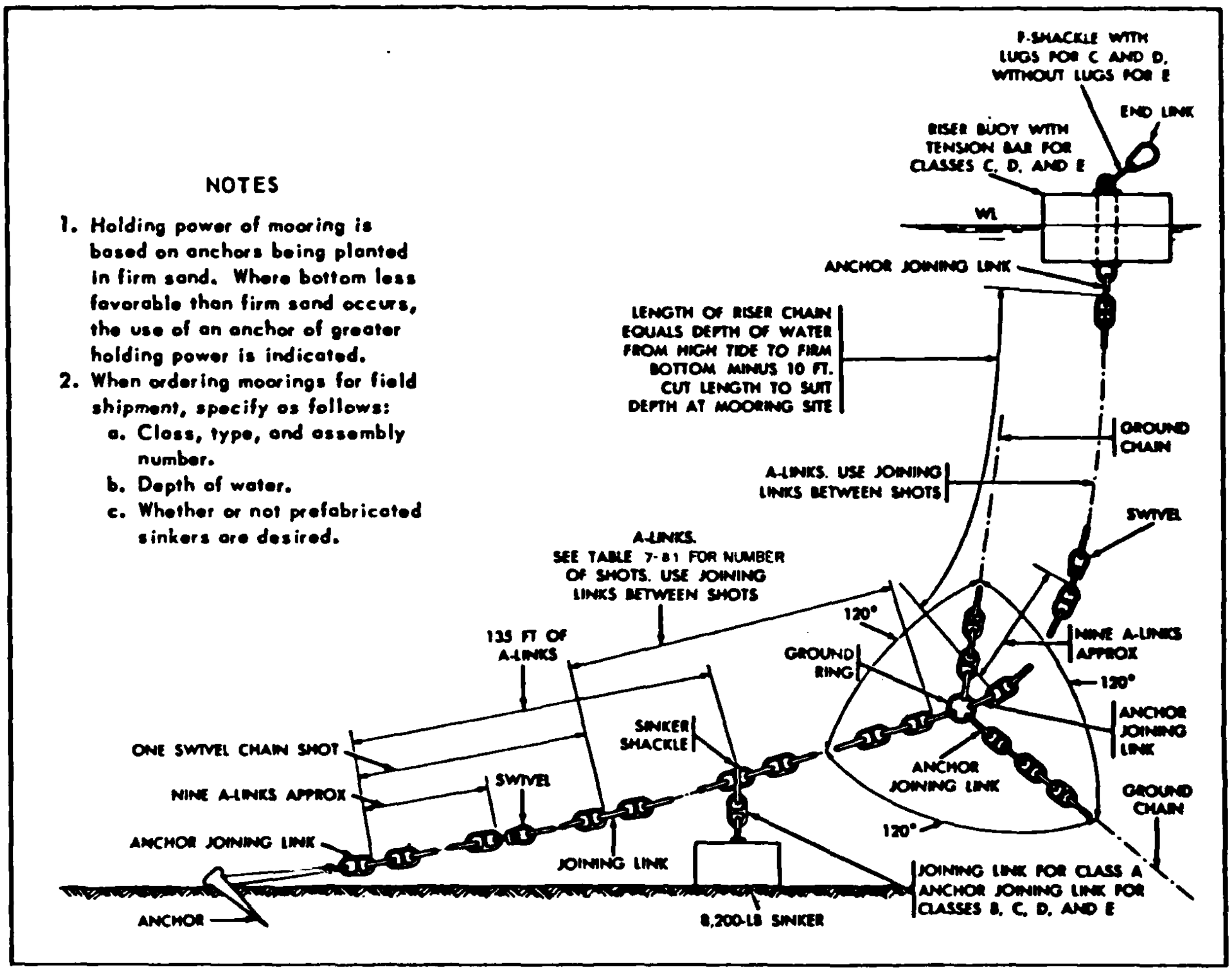
Mooring	Anchor	Coordinates in Feet North	East	Planned or Actual
1	A	394955	1531617	Planned
	B	394278	1531864	"
	C	394403	1531154	"
2	A	394987	1532457	Actual
	B	394279	1532643	"
	C	394465	1531950	"
3	A	394874	1533443	Planned
	B	393943	1533361	"
	C	394479	1532595	"
4	A	393628	1532165	Planned
	B	393308	1531286	"
	C	394229	1531448	"
5	A	394010	1532924	Planned
	B	393200	1532456	"
	C	394010	1531988	"
6	A	392954	1532373	Actual
	B	392707	1531696	"
	C	393417	1531821	"
Walan		397070	1532462	Actual
Cliff		395382	1534587	"

DESIGN OF MOORINGS

For the 1978 installations, the majority of the required material had already been acquired by OICC TRIDENT and thus the first design had to be tailored to utilize the available components. These components had been ordered in compliance with the design criteria for a free swinging riser-type mooring with sinker, Figure 2-6, given in the Navy Design Manual[6], for a Class C mooring (which has a horizontal holding power of 100,000 pounds).

The basic design criteria were to restrict the movement of anchored YC and YFN ammunition barges to a watch circle radius of less than 50 feet in a 100 mph wind and a 2 knot current in water with depths up to 90 feet. The estimated horizontal loading for design purposes was 12,000 pounds applied in any direction.

Under a 12 kip loading, the standard Class C mooring would have a watch circle radius greater than 70 feet in a water depth of 90 feet. Since the



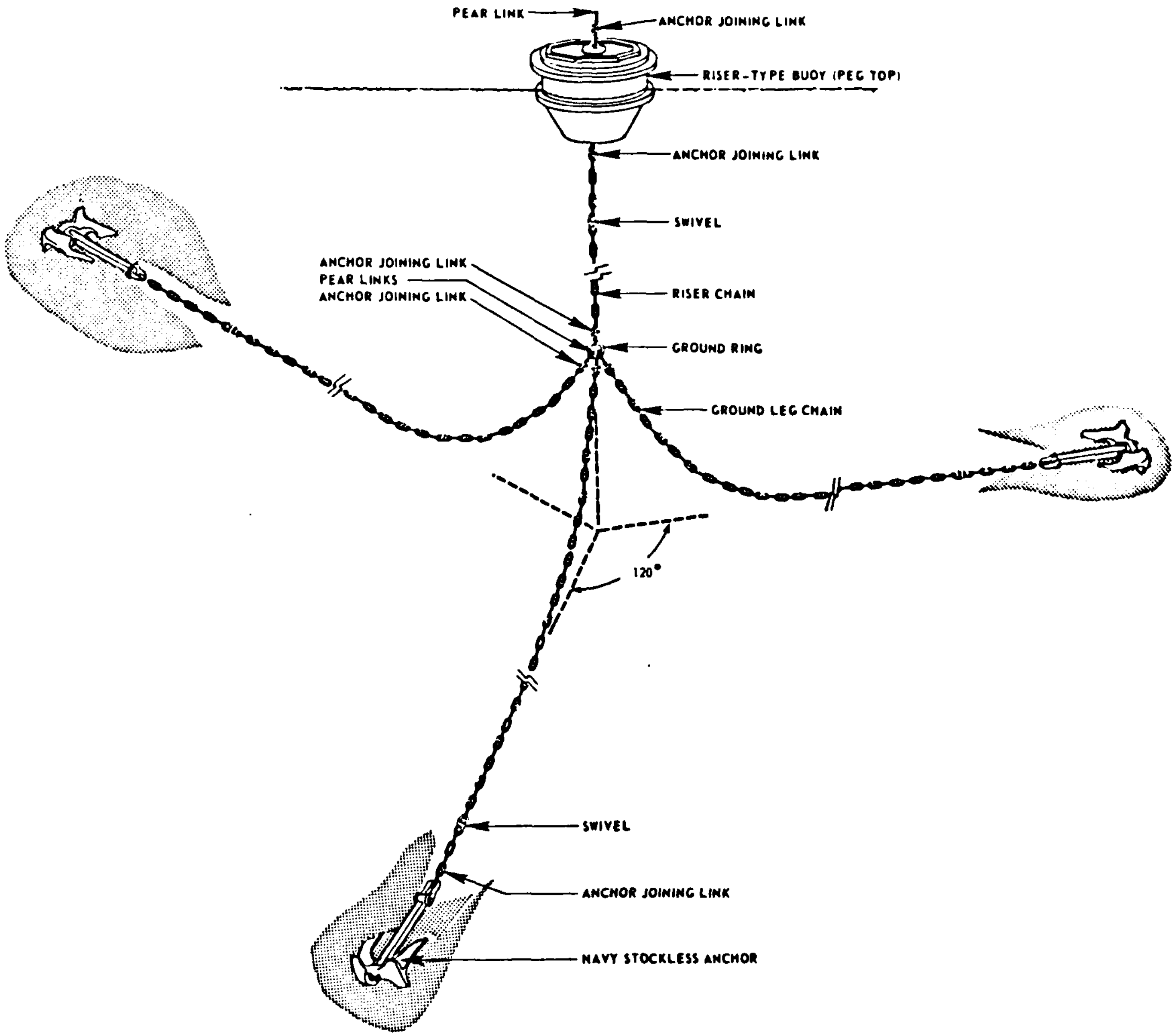
FREE-SWINGING RISER-TYPE MOORING WITH SINKER

FIGURE 2-6

resulting barge swing would exceed the Indian Island mooring criteria, a modified mooring design was required to restrict the range of movement under load.

Although other mooring options were explored [5], it was concluded that a free-swinging shortened riser mooring would most effectively utilize the available components, could be implanted using known techniques, and could be designed to meet the loading and watch circle specifications. The selection rationale and the design approach used are given in greater detail in Appendix A.

The design of the moorings for the 1983 installations at Indian Island followed essentially the same logic as for those installed in 1978. However, Class E hardware had been procured in advance by NUWES, Keyport. Also, some design changes were required because of the observed movement and potential overloading of mooring number 1, the differences in bottom contours that had to be accommodated in mooring number 3, and lighter hardware. Additionally, installation experience with the initial design had been gained in 1978 and more time for a thorough design analysis was available for the 1983



SHORTENED-RISER, FREE-SWINGING MOORING USED AT INDIAN ISLAND

FIGURE 2-7

installation. This Phase II design effort is also described in Appendix A.

The differences between the shortened-riser mooring used at Indian Island and the standard Class E free-swinging riser-type mooring with sinker can be illustrated by comparing Figure 2-6 with Figure 2-7. An obvious difference is that the latter does not employ any sinkers but relies completely on the anchors to provide the required holding power.

Both the standard and the shortened-riser mooring comprise three anchors and three ground legs connected to a centrally located ground ring.

The ground legs radiate outward to the anchors at a 120° spacing and the ground ring is connected to the surface mooring buoy by a length of riser chain.

It may be noted in Figure 2-6 that the "length of riser chain equals depth of water from high tide to firm bottom minus 10 feet. Cut length to suit depth at mooring site." The chain connection on the peg-top buoys used is about 7 feet below the waterline and the tidal height is 8 to 10 feet. This means that even if the ground legs were taut, the ground ring would rest on the bottom for the majority of the time. This allows considerable movement of the mooring buoy before it applies a significant restraining force to movement of the moored vessel.

If the mooring shown in Figure 2-7 is properly installed, the anchor flukes will be firmly implanted and each ground leg chain will rise in a catenary to the ground ring. When a horizontal force is applied to the buoy, the tension immediately increases in the shortened riser chain as the ground ring rises further. The resisting horizontal force exerted by the opposing anchor or anchors significantly restricts the allowable movement of the mooring buoy. The design problem is to determine the amount by which the riser must be shortened to restrict the watch circle of buoy and barge movement to the specified value without applying too great a load on the system components. These calculations are described in Appendix A and the results applicable to each mooring will be covered later in the description of construction operations.

The lengths of the ground legs for mooring numbers 1, 2, and 6 are 416 feet each whereas those for mooring numbers 3, 4, and 5 are 540 feet each. The anchors for mooring number 1 were originally 20,000 pound Navy Stockless without stabilizers; those for mooring numbers 2 and 6 are 18,000 pound Navy Stockless without stabilizers. For mooring numbers 3, 4, and 5 the anchors used were 9,000 pounds, with stabilizers, and the replacement anchors for mooring number 1 were 25,000 pounds, with stabilizers. The design manual DM-26 gives a stabilizer design for 25,000-pound anchors which could not be followed in this project because the required sizes of pipe sections were not available. Therefore, different stabilizers were designed and fabricated for the mooring number 1 replacement anchors.

3.0 PROJECT INPUT FROM VARIOUS ORGANIZATIONS

The initial assignment of the Phase II Indian Island Mooring Project was received in the Spring of 1982. On 28 April 1982, CHESNAVFACENGCOM was requested by Western Division, Naval Facilities Engineering Command (WEST-NAVFACENGCOM) to revise the moorings' designs and manage their installation including procurement of all required materials [2]. The Commander, Naval Facilities Engineering Command (COMNAVFACENGCOM) informed WESTNAVFACENGCOM that it would provide all necessary funds for the design and installation. On 3 June 1983, CHESNAVFACENGCOM accepted the tasking [7].

The three existing moorings were inspected by CHESNAVFACENGCOM as part of the Fleet Mooring Maintenance Program on 8-10 November 1982. Reference [8] from CHESNAVFACENGCOM to NUWES described the unsatisfactory condition of mooring number 1. In reference [9], NUWES requested that CHESNAVFACENGCOM redesign the mooring to withstand larger loads. Further, it was requested that mooring number 1 be repaired during Phase II installation of mooring numbers 3, 4, and 5.

On 13 January 1983, CHESNAVFACENGCOM requested tug boat and crane barge services from the 144th Transportation Battalion, Washington State Army Reserve National Guard (WSNG) [10] which WSNG agreed to provide [11]. On 4 February 1983, UCT-TWO requested funds for diver support [12] which CHESNAV-FACENGCOM provided to COMCBPAC, Pearl Harbor, HI on the same day [13].

CHESNAVFACENGCOM [14] requested Puget Sound Naval Shipyard (PSNS), Bremerton, WA to:

- o Install tension bars in and refurbish three Mark II peg-top buoys,
- o Install stabilizers on three 25,000 pound anchors, and
- o Provide riggers and rigging equipment.

PSNS received their funding on 17 May from WESTNAVFACENGCOM [15].

Thus, there were five organizations that were directly involved on site in Phase II of the Indian Island Mooring Project: CHESNAVFACENGCOM, WSNG, PSNS, UCT-TWO, and NUWES. The contributions made by each organization do not lend themselves to description in the form of a work breakdown structure nor in an

organization chart form. The narrative below gives a general overview of the personnel, equipment, and material provided by each of these groups. With this initial introduction, the individual contributions can then be ascertained from the description of construction operations in the sections that follow.

CHESNAVFACENGCOM PROJECT RESPONSIBILITIES

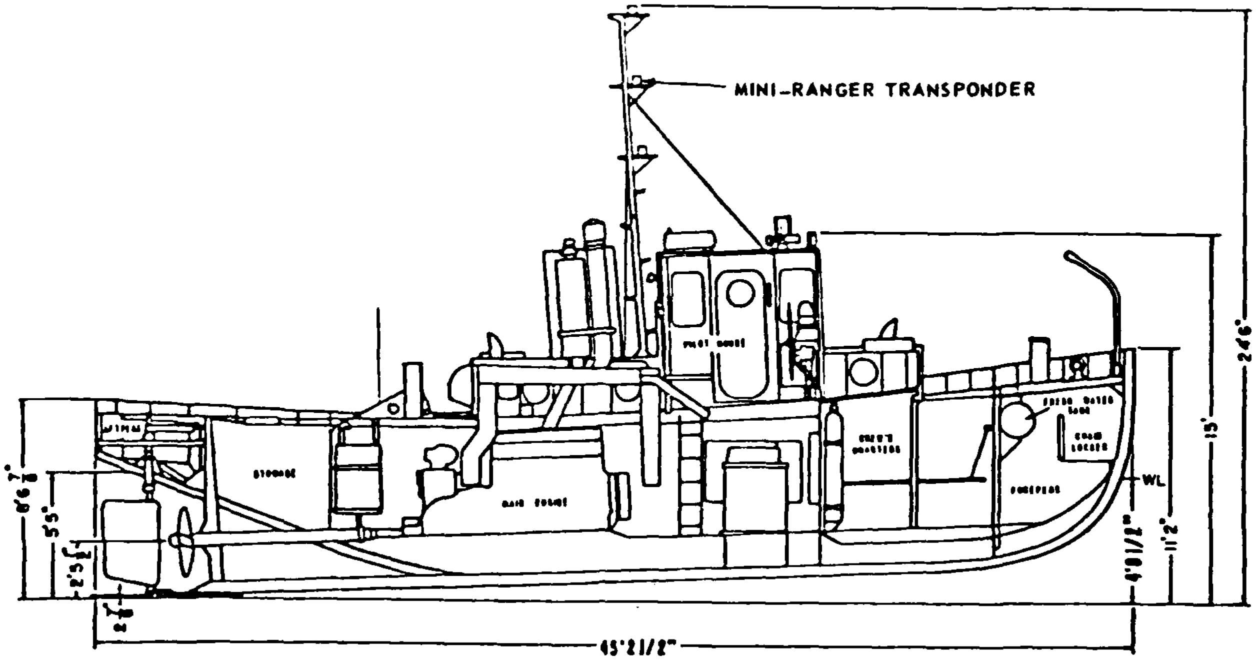
Assigned to CHESNAVFACENGCOM was the responsibility to provide overall direction for the project during the preparation and construction operations stages, to design the moorings, and to coordinate project execution with the user, NUWES. A mooring design was developed to meet the user's performance requirements that employed the components of a Class E, Free-Swinging Riser-Type Mooring and which was adaptable to the environmental characteristics of the Indian Island site. Additional design work included a redesign of mooring number 1 to withstand higher anticipated loadings due to its ready accessibility to local marine traffic.

It was left to CHESNAVFACENGCOM to identify and coordinate modification and refurbishment of mooring materials, construction platforms, construction equipment, and the personnel required to execute the project. Also, this organization was responsible for providing project logistics, planning, and engineering support as well as specifying the quality control measures to be followed during construction and to define, supervise, and analyze the facility acceptance tests.

From the Ocean Construction Equipment Inventory (OCEI), CHESNAVFACENGCOM was to provide Mini-Ranger navigation equipment and services and communications equipment. They were also to prepare a Project Execution Plan [16], provide field engineering and design support, furnish photographic equipment and personnel to document construction operations, and to prepare a Project Completion Report and as-built drawings.

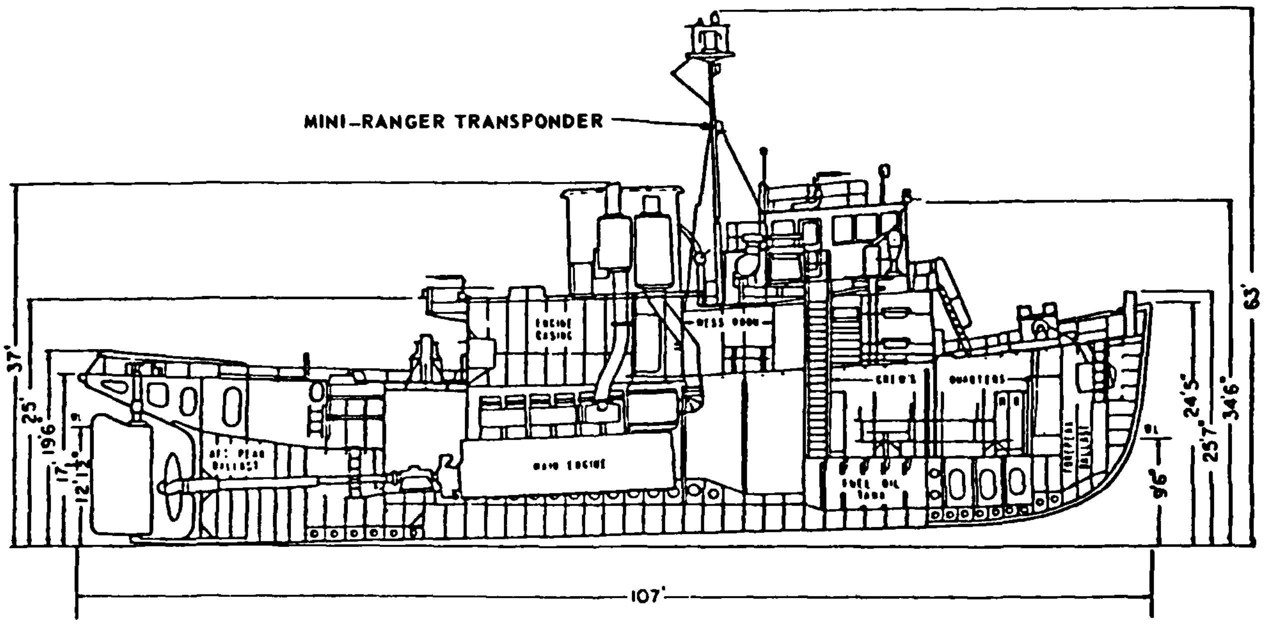
WASHINGTON STATE NATIONAL GUARD, TACOMA, WA (WSNG)

During the Phase I Indian Island Mooring Project, arrangements were made with the 144th Transportation Battalion of the WSNG to provide marine equipment and operating personnel to assist in construction operations. This organization furnished a 45-foot tug, a 100-foot tug, and a 60-ton crane barge for Phase I; it was logical to request similar cooperation



45 FOOT ARMY TUG DESIGN 320 - INBOARD PROFILE

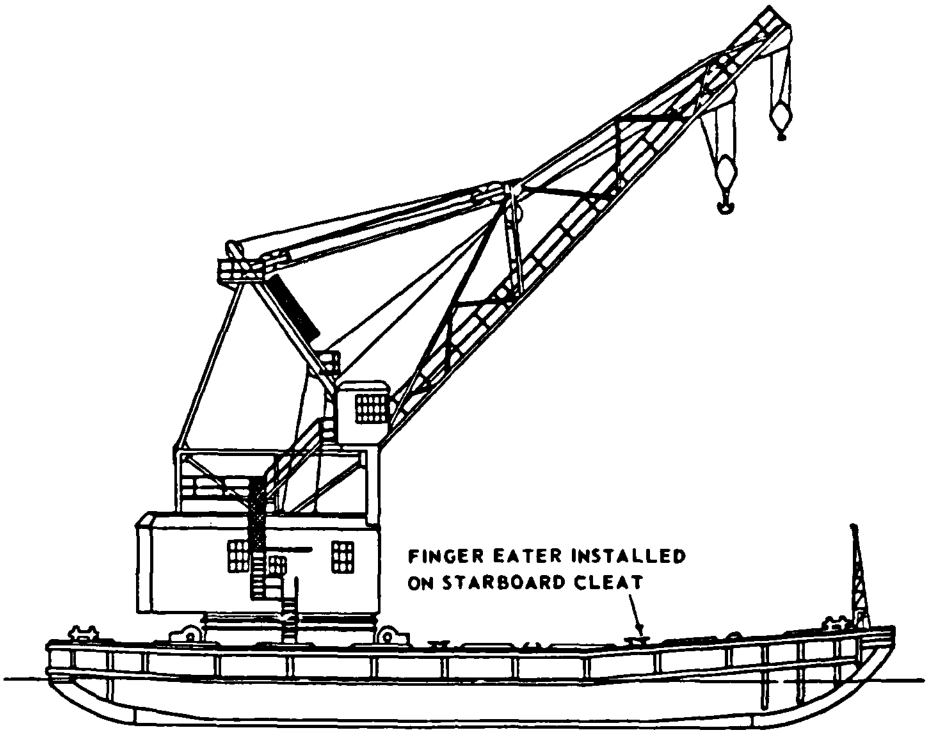
FIGURE 3-1



100 FOOT ARMY TUG DESIGN 3003 - INBOARD PROFILE

FIGURE 3-2

during the Phase II operations. This was done and a favorable reply was received [11]. Inboard profiles of the 45-foot tug and the 100-foot tug are given in Figures 3-1 and 3-2. The small tug is powered by a 200 hp diesel and has a tow rope pull at zero speed of about 5000 pounds. The large tug,



60 TON ARMY CRANE BARGE DESIGN 413

FIGURE 3-3

with a 1200 hp diesel, is capable of a dead pull of 25,000 pounds and thus could be used to apply the required 12 kip horizontal test loading on the completed moorings.

The WSNG crane barge mounts a revolving crane with a nominal 60-ton lift capacity at a 73-foot radius. The outboard profile of the crane is shown in Figure 3-3. The forward deck of the crane is relatively open to permit storage of buoys, anchors, and rigging gear on the deck. It does, however, have two small an outreach to work over the bow and therefore the hoisting and lowering work must be performed overside. When handling heavy weights, this can create problems due to heeling of the crane barge.

WSNG also agreed to provide for the safety of all personnel and equipment aboard the crane barge and tugs during the construction period and to perform any necessary modification or outfitting of these platforms to ready them for construction operations. Their responsibilities also included receiving project equipment and making ready for transport to and from Indian Island aboard the barge or the tugs.

Additionally, WSNG was responsible for the following:

- o Platform maneuvering and station-keeping
- o Crane operator

- On-loading of mooring components and assisting with rigging
- Fathometer aboard the 100-foot tug
- Batteries for Mini-Ranger transponders

PUGET SOUND NAVAL SHIPYARD (PSNS)

Numerous miscellaneous responsibilities were assigned to PSNS involving supplying materials and equipment, fabricating and installing equipment aboard the construction platforms, providing personnel for various operations, and transporting materials and equipment to the construction site.

PSNS provided five wharfbuilders to perform all deck operations involved in the rigging and mooring installations. They also assigned to the project a welder with required hardware and equipment and provided for the safety of all personnel and equipment on deck during rigging and mooring installations.

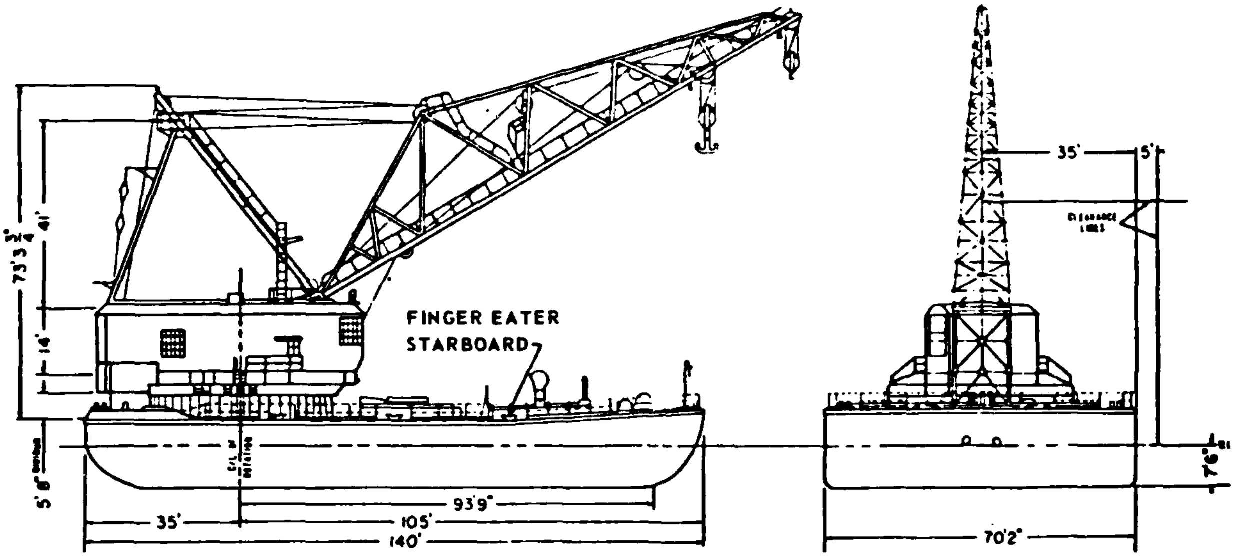
The yard fabricated and installed tension bars to the peg-top buoys for mooring numbers 3, 4, and 5 and also refurbished the three buoys. They fabricated and installed stabilizers on three 25,000-pound anchors provided by PSNS to replace the anchors on mooring number 1 and identified, fabricated, or provided for all rigging hardware, tools, and equipment necessary for installing the moorings with the WSNG crane barge.

The shipyard also provided calibrated load cells and rigging for the pull tests and for the marker buoy moorings, assisted with on-site logistics, and coordinated with CHESNAVFACENGCOM as necessary on the services, equipment, materials, and personnel provided by PSNS and their transport to the construction site. During the construction operations, when a failure occurred in the rigging system on the Army crane barge, PSNS furnished a replacement Navy YD crane barge, Figure 3-4, together with a crane operator, to enable CHESNAVFACENGCOM to complete the construction operations.

UNDERWATER CONSTRUCTION TEAM TWO (UCT-TWO)

UCT-TWO provided a five-man dive team to support the Indian Island Mooring Project. The team was responsible for the safety of all personnel and equipment used in diving operations, including medical evacuation and the use of a recompression chamber.

Equipment and materials furnished by the team comprised all dive equipment, a dive boat, a truck to transport diving equipment, transits for back-up navigation, hand held radios, and wire cutters for diver use.



NAVY YD CRANE BARGE FURNISHED BY PUGET SOUND NAVAL SHIPYARD

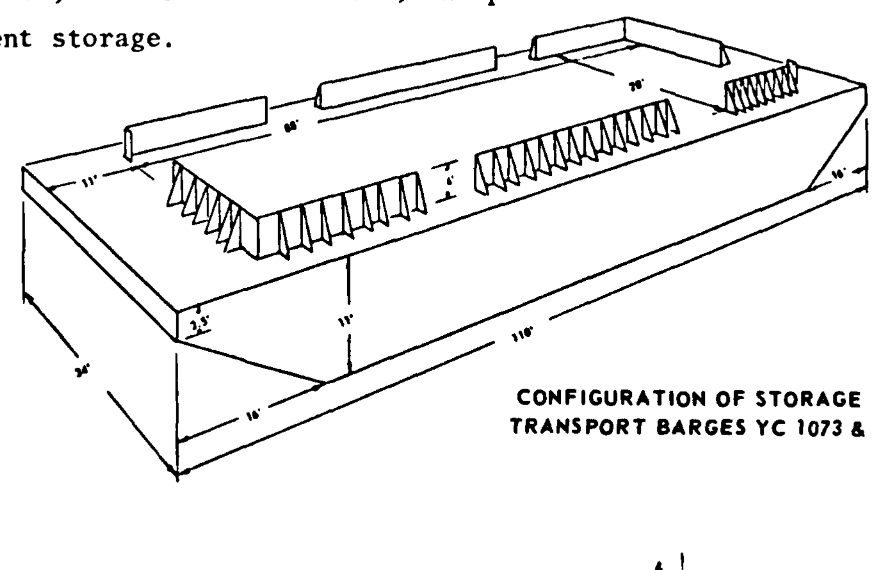
FIGURE 3-4

The services provided by UCT-TWO included underwater inspections and other underwater tasks associated with mooring implantment, assistance in deck operations under the supervision of the foreman wharfbuilder, operation of the dive boat as a navigation aid, and general assistance as required in all phases of the construction operations.

NAVAL UNDERSEA WARFARE ENGINEERING STATION, KEYPORT (NUWES)

The NUWES Detachment, Indian Island, provided two YC barges as depicted in Figure 3-5. These barges were used to transport anchors, buoys, chain, and other rigging gear to the construction site and were tied up alongside the crane barge during implantment of the moorings.

In addition to the barges, NUWES provided a standby tug, logistic support as needed, access to work sites, and provided secure areas for material and equipment storage.



CONFIGURATION OF STORAGE AND
TRANSPORT BARGES YC 1073 & 1107

FIGURE 3-5

4.0 CONSTRUCTION OPERATIONS

Beginning on 16 August 1983, the on-site preparation and pre-rigging for the mooring installation were underway as well as the efforts to locate navigation markers ashore to establish a basis for the location of various critical elements of the mooring buoy location procedure. For convenience in delineating the steps involved in the various facets of construction operations, these elements are separated under headings such as: Resolution of Problems with Navigation Systems; Preparation and Pre-Rigging; Mooring Buoy Installation and Pull-Tests; and Diver Inspection.

RESOLUTION OF PROBLEMS WITH THE NAVIGATION SYSTEMS

Mini-Ranger receiver/transponders (R/Ts) were deployed on the large and small Army tugs with the shore transponders at "Kala," "Walan," and "Crane." The shore stations utilized two 12 VDC car batteries each, which were supplied by the UCT-TWO Detachment. WSNG also supplied four 12 VDC military batteries but these were not used due to potential acid leakage during transportation and setup. The UCT-TWO car batteries were of the "maintenance free" type which eliminated the danger to personnel from acid spillage.

The R/T units were mounted on the masts of the tugs; as can be seen in Figures 3-1 and 3-2, this located the units approximately amidships. This location could introduce a 10-foot to 15-foot error abeam and 20-foot to 40-foot error lengthwise when overboarding the marker buoys. The use of an 18-foot whaler could reduce this error when construction tolerances of only $\pm$ 20 feet are required. There was also a 6 meter difference in readout when the console unit was placed on one tug or the other.

The console unit, which could be employed on either tug, was calibrated over a measured 250 meter range with both R/Ts and all of the shore station transponders. The operating distance between shore stations was 1000 to 1500 meters. The range unit at "Crane" was partially obscured by the existing wood (old) ammunition pier and docked barges. The "Crane" station was eliminated after the first day because of this interference.

The "Kala" range station was masked during operations with the crane barge. There may have been range holes experienced due to the elevation of "Kala." As a result of the distance variations in the readout from "Kala," the use of this station was also discontinued.

The elimination of "Crane" and "Kala" resulted in discontinuing the use of the Mini-Ranger system and shifting to triangulation by transits positioned at "Cliff" and "Walan."

Transits were employed at this point in the project to locate the marker buoys, anchor installation locations, mooring buoy locations, and the buoy movements experienced during the scheduled pull tests. The transits were located at "Cliff" and "Walan." All transit readings from these bench marks were oriented to the Washington State Lambert North Zone Coordinates described earlier.

The location of "Cliff" was offset 7 feet toward "Walan" because existing vegetation restricted the line of sight to the planned mooring area. The offset coordinates were calculated using the given coordinates of "Walan" and "Cliff" and measuring the offset along the line connecting these two stations.

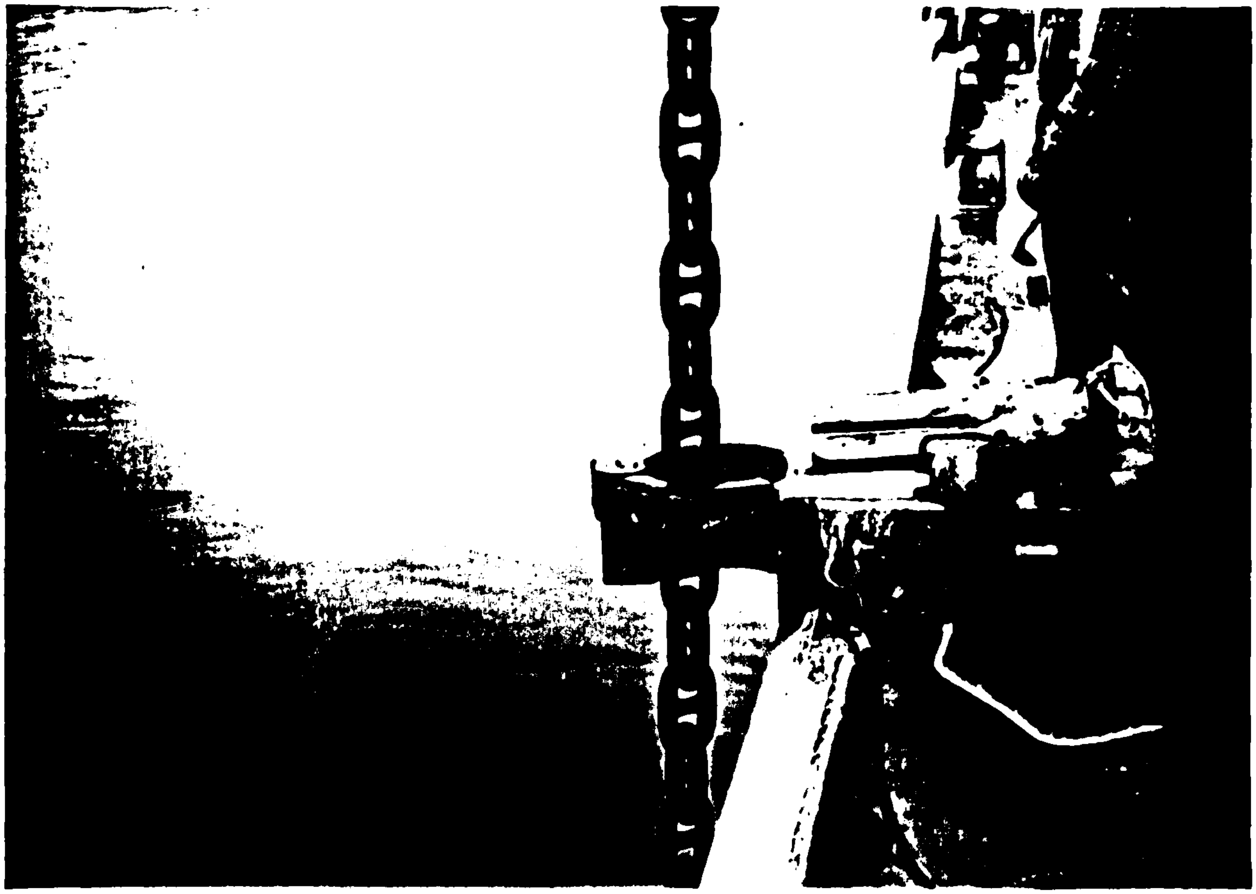
Prior to commencement of the construction operations, the transit angles from both "Cliff" and "Walan" with the baseline between them were calculated for all mooring buoy, crown buoy, and marker buoy positions so that sighting-in of a desired location could be accomplished within a minimal time frame.

The technique generally employed to place the dive boat at a desired location was, first, to have the boat align itself with a sight line from "Walan" and then head toward "Walan" along the sight line. When the boat crossed the sight line from "Cliff," the transit operator at "Cliff" would signal the crossing and the prescribed action would be taken, i.e., overboarding an anchored buoy or stopping the boat. Radio contact was maintained between the dive boat, crane barge, and the two transits.

PREPARATION AND PRE-RIGGING

In the Phase I operations it had been planned to lay out on the crane barge deck all of the rigging gear required for one mooring buoy installation including the buoy, the riser chain, the ground ring, three ground leg chains, and three anchors together with their respective crown buoys. This created considerable confusion on deck and required special techniques for overboarding the chain.

During early discussions for Phase II with the wharfbuilders at PSNS, it was pointed out that a device called a "Finger-Eater" (FE) could be



THE "FINGER EATER" WITH FORKED PLATE CHAIN STOPPER READY FOR INSERTION

FIGURE 4-1

attached to the deck of the crane barge that would greatly simplify the operation of connecting shots of chain and lowering the assembly into the water.

The "Finger-Eater," shown in Figure 4-1, is a device that serves to restrict the lateral movement of a chain being lowered through it and as a chain-stopper to support the chain and attached load when the stopper is engaged. The fabricated FE is secured to the deck edge. The inboard arms of the FE fit under the arms of a standard cleat and are locked to the inboard side of the cleat with a cross bar that is secured tightly by pins and wedges.

The outboard structure of the FE overhangs the deck edge and comprises an open chock which can be closed by means of a swinging pinned arm after the chain moves into the chock. A fork-like plate slides in place atop the FE to fit between chain links; this serves as a chain stopper when the upper link is lowered to rest upon it.

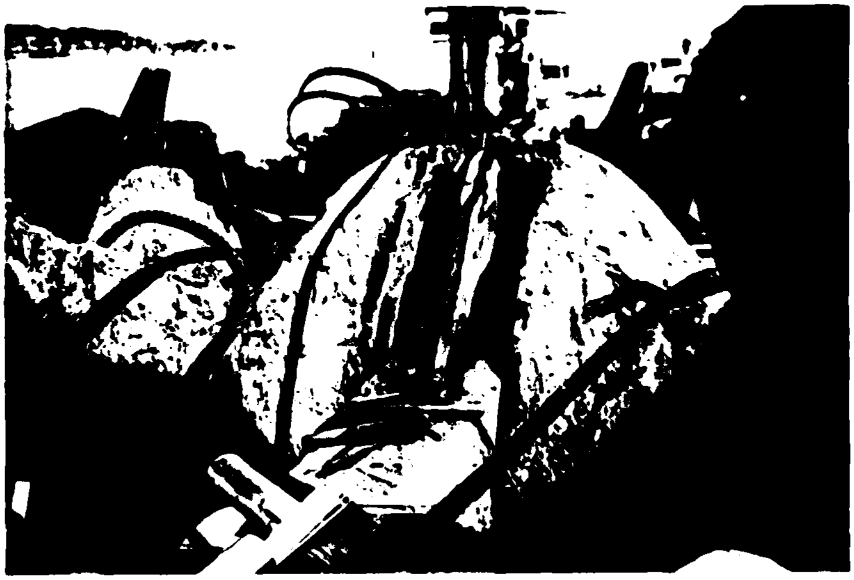
In preparation for the Phase II effort, the FE was installed on a forward starboard cleat on the Army crane barge. This permitted a revision in the earlier technique of mooring system installation. It allowed the buoy, chain, and anchor to be transported to the implantment site aboard a YC barge which then could be secured to the port side of the crane barge. As each element of the system was required, it could be lifted by the crane from the YC, swung across to the starboard side of the crane barge and connecting links could then be used to join the element on the crane hook with the chain supported in the FE. This would leave the forward deck of the crane barge open and free of gear for more effective use as a working area.

A certain amount of preparation and pre-rigging was involved to capitalize on the potential efficiency of this mode of installation operations. As has been stated earlier, the anchors were fitted with wedges to lock the flukes in an open position. The wedges were fabricated at PSNS and then were welded to the anchors on the deck of the Indian Island ammunition pier which also served as a staging area for much of the gear. Wire rope slings were also attached to the anchors so that they could be lowered to the bottom with the shanks horizontal and the flukes down.

Figure 4-2 shows the wedge installed in one of the 25000-pound anchors to be used in replanting Mooring Buoy #1 and Figure 4-3 shows a similar wedge installed in one of the 9000-pound anchors to be used in the three new moorings.

Figure 4-4 illustrates the type of sling that was employed in lowering the anchor to the bottom. Also evident in Figure 4-4 is a typical stabilizer welded across the base of the flukes on the 9000-pound anchor to prevent the anchor from tipping over when dragged along the bottom thus ensuring that the flukes would dig in securely. Similar devices, using angle and plate sections were welded to the 25,000-pound anchors at PSNS.

The day prior to an installation, there was some pre-rigging done on

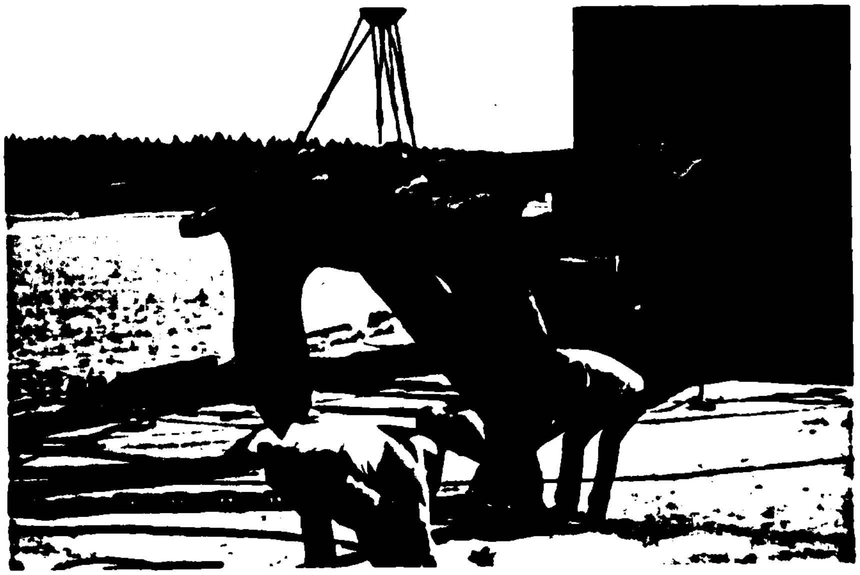


WEDGE BEING WELDED TO SECURE FLUKES ON 25000# ANCHOR

FIGURE 4-2

WEDGE WELDED IN PLACE TO SECURE FLUKES ON 9000# ANCHOR

FIGURE 4-3



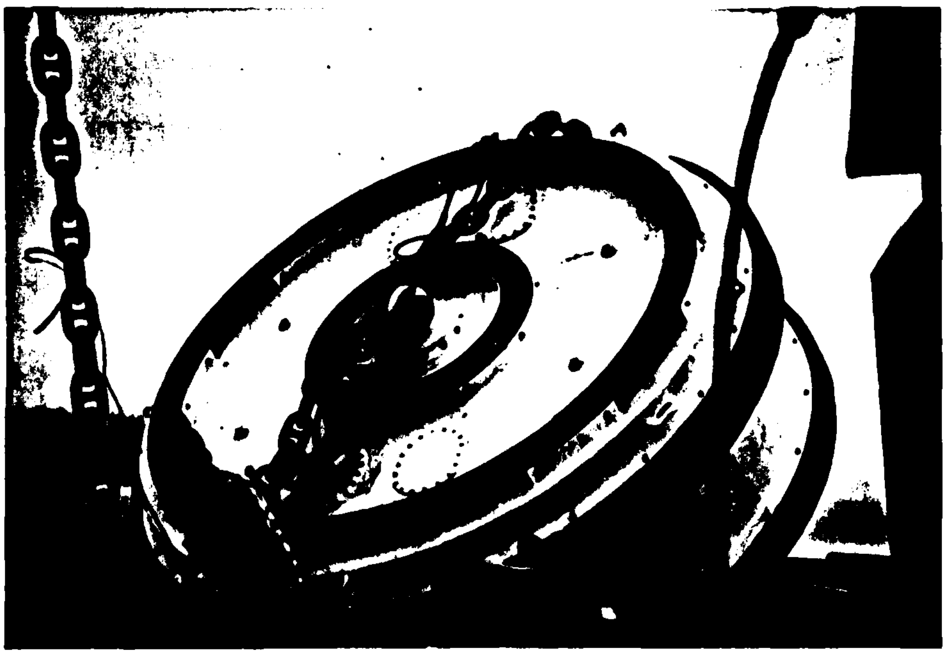
SLING RIGGED ON 9000# ANCHOR FITTED WITH STABILIZER

FIGURE 4-4

FIGURE 4-5

GROUND RING WITH ANCHOR LEGS ATTACHED

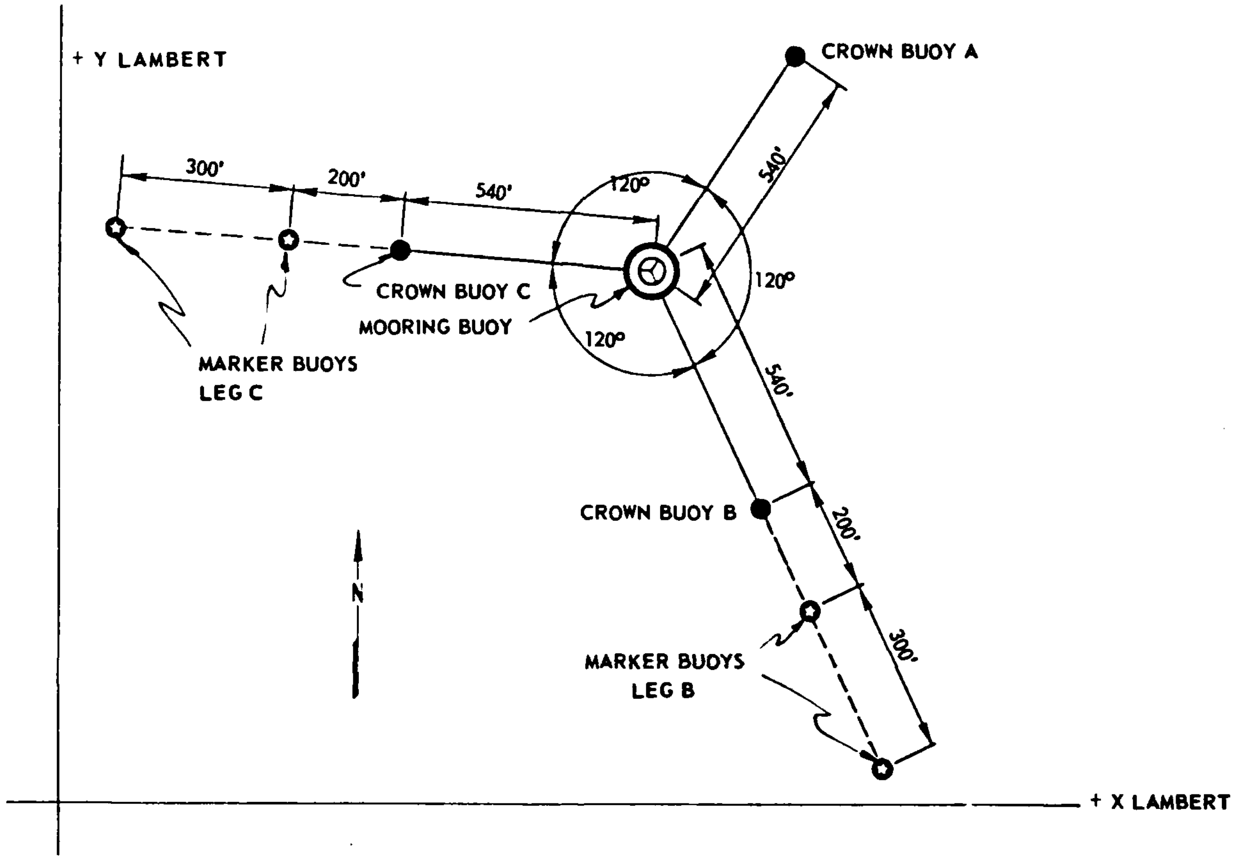
FIGURE 4-6



THROW-OFF LEGS BEING SECURED TO MOORING BUOY

the mooring buoy and the chain attached to it. As shown in Figure 4-5, the riser was attached to the ground ring with an anchor joining link. Also attached to the ground ring with anchor joining links were two shots (90 feet each) of ground leg chain. These were referred to as the "throw-off legs." The opposite ends of the two throw-off legs were then brought around and secured to the top of the mooring buoy, as illustrated in Figure 4-6, and this entire sub-assembly was stowed in the YC barge. The purpose of this prerigging will become evident during later descriptions of the mooring implantment.

Another element of the preparation for a mooring installation was the pre-installation deployment of marker buoys to be used as navigational aids. Although slightly different marker buoy positions were used in the four installations, the layout given in Figure 4-7 is typical.



TYPICAL ARRANGEMENT OF CROWN BUOYS
AND MARKER BUOYS FOR MOORING INSTALLATION

FIGURE 4-7

The transit angles from Cliff and Walan were predetermined so that either the dive boat or the small tug could be used to put the buoys in place. The buoys used were pumpkin floats, Figure 4-8, secured to small concrete anchors, Figure 4-9, by means of a six thread manila line. Near the surface, a 20-foot loop was formed in the manila line using a 10-foot length of bungee cord which would stretch out to 20 feet when the buoy was lifted. This allowed the marker mooring to remain relatively taut with the rise and fall of tide. Figure 4-10 shows the dive boat being used for marker placement.

The first marker buoy was placed at the point at which the peg-top

PUMPKIN FLOATS USED
AS MARKER BUOYS

FIGURE 4-8

CONCRETE ANCHOR CLUMPS
USED WITH MARKER BUOYS

FIGURE 4-9

UCT-TWO DIVE BOAT

FIGURE 4-10

mooring buoy was to be located and a second marker was placed at the point where the first leg anchor was to be lowered. These markers defined the path for laying the first ground leg. For the second and third legs, the marker buoys were to be used as sighting targets so that the implantment vessel could be guided along a straight path from the mooring buoy to the anchor drop point as the six shots of ground leg chain were lowered to the bottom.

INSTALLATION OF MOORING BUOY #5

The first installation was that of Mooring Buoy #5. Work began on site with the installation of marker buoys on the morning of 22 August 1983. At this point, the Mini-Ranger III was still considered to be the primary navigational device and ranges from reference stations at Kala Point and Crane, working with the master station on the 45-foot tug were used to establish marker buoy positions. The marker buoys were positioned as prescribed and their anchor clumps dropped into place.

After checking the marker buoy positions, several were found to be unsatisfactory. In the afternoon of that day, transits were set up at Cliff and Walan and those marker buoys were repositioned using the dive boat so that the stage was set for the Mooring Buoy #5 installation.

On the morning of 23 August, the Finger-Eater supplied by PSNS was modified to fit the forward starboard cleat on the Army crane barge and readied for operation. A YC barge had been previously loaded with the equipment and pre-rigged units required for the mooring.

Typically, four vessels were used for the implantment operations. The 142-foot by 58-foot Army BD crane barge and the 110-foot by 34-foot Navy YC barge were secured side by side with their bows at the same fore-and-aft location and the port side of the crane barge secured to the starboard side of the cargo barge. The bows were separated only by fenders but the stern of the cargo barge was breasted out from the side of the crane barge.

The 100-foot Army tug bow was wedged and secured into the after opening between the barges. This permitted the large tug to apply forward thrust to the three-vessel tow; it also had reasonable steering control over the tow. In order to exercise more finely tuned maneuvering control, the 45-foot tug was used at the forward end of the tow. It could move from the port side of the cargo barge around to the starboard side of the crane barge to push the bows into

any desired position relative to the mooring systems elements or the marker buoys.

At 0930 on 23 August, the assembled tow moved out to the buoy that marked the position of the anchor for ground leg A of Mooring Buoy #5.

The anchor for leg A had been pre-rigged with the wire rope leveling sling and the crown line attached. The first shot of ground leg chain was shackled to the shank of the anchor. The anchor was picked up with the crane by the end of the chain from the deck of the cargo barge, swung across the crane barge deck and lowered into the water, Figure 4-11. As the crown line trailed over the crane barge deck, the first shot of chain was moved into the FE and the gate of the FE closed. The anchor was then lowered to a point just above the bottom and the chain secured with the forked plate in the FE.

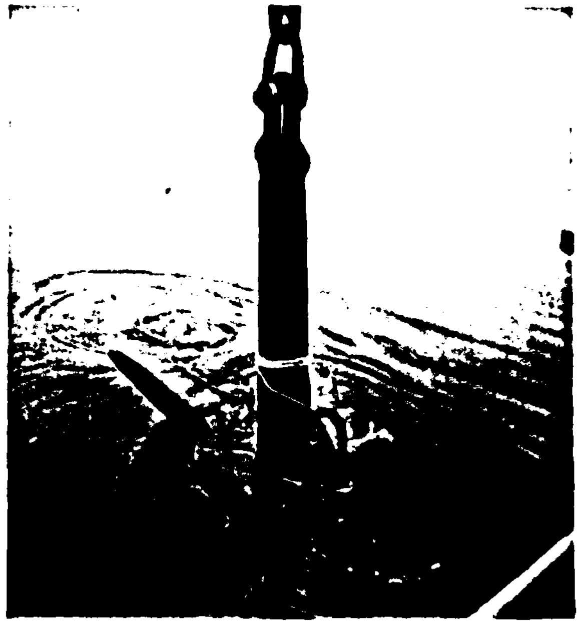
The crane next set the crown buoy on the crane barge deck near the FE and picked up tension on the crown line so that a cripple connection, Figure 4-12, could be made between the crown buoy and the crown line. The anchor was then lowered to the bottom with the crown line to the point where the crown buoy, Figure 4-13, could be pushed overboard.

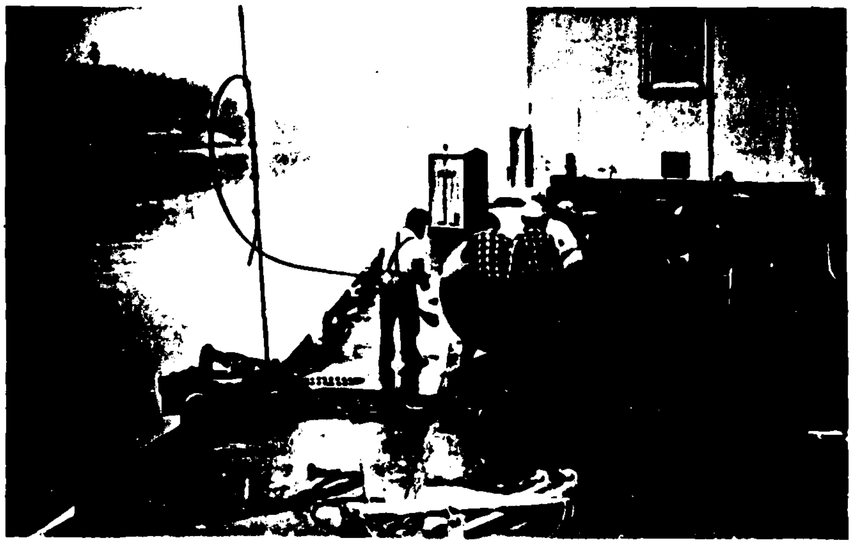
To lay ground leg A, the crane picked up the second shot of chain from the cargo barge and the end was secured with a detachable link to the end of the first shot which was still hanging in the FE. The crane relieved the load on the FE forked plate, the plate was removed, and the crane began lowering the second shot of ground leg A chain through the FE as the tug began pushing the two barges toward the marker buoy that designated the Mooring Buoy #5 location. This procedure was continued, adding shots of chain until the end of Shot 6 of ground leg A approached the FE and the forked chain stopper plate was inserted. By this time, the crane barge was alongside the Buoy #5 location marker. A hard pull was exerted by the tug to straighten out leg A. This occurred at about 1130.

Swinging the crane boom over the cargo barge, the top of Mooring Buoy #5 was picked up by one hook and the ground ring was picked up by the other hook as shown in Figure 4-14. When the boom was swung around to the starboard side of the crane barge, the ground ring was lowered to the point where it could be secured with an anchor connecting link to the mooring buoy end of ground leg A. The load on the FE was relieved by lifting on the ground ring, the chain stopper plate was removed, and the FE opened as seen in Figure 4-15. The buoy was raised to take the load, the crane hook disconnected from the ring, and the riser and buoy lowered clear of the side of the crane barge, Figure 4-16.

LOWERING THE ANCHOR FOR
LEG A INTO THE WATER

FIGURE 4-11





CRIPPLE CONNECTION ON
CROWN LINE FROM
LEG A ANCHOR

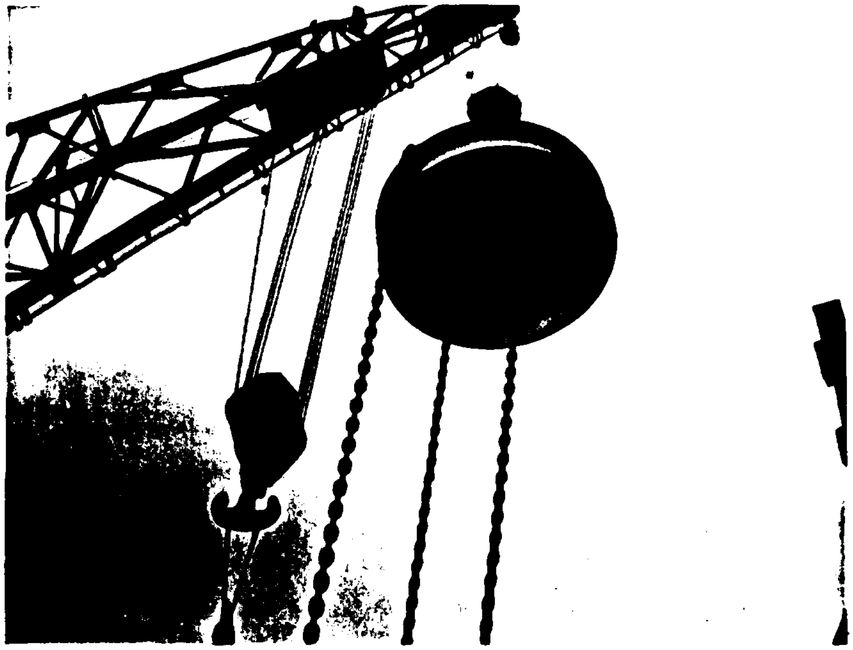
FIGURE 4-12

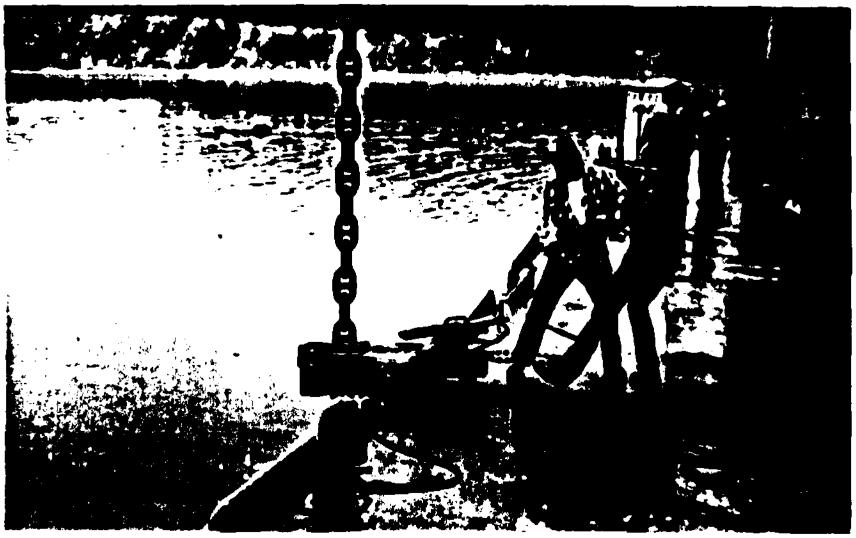
PUSHING THE LEG A
CROWN BUOY OVERBOARD

FIGURE 4-13

LIFTING MOORING BUOY #5 AND ITS GROUND RING NOTE RISER AND TWO THROW-OFF LEGS ATTACHED TO BUOY

FIGURE 4-14



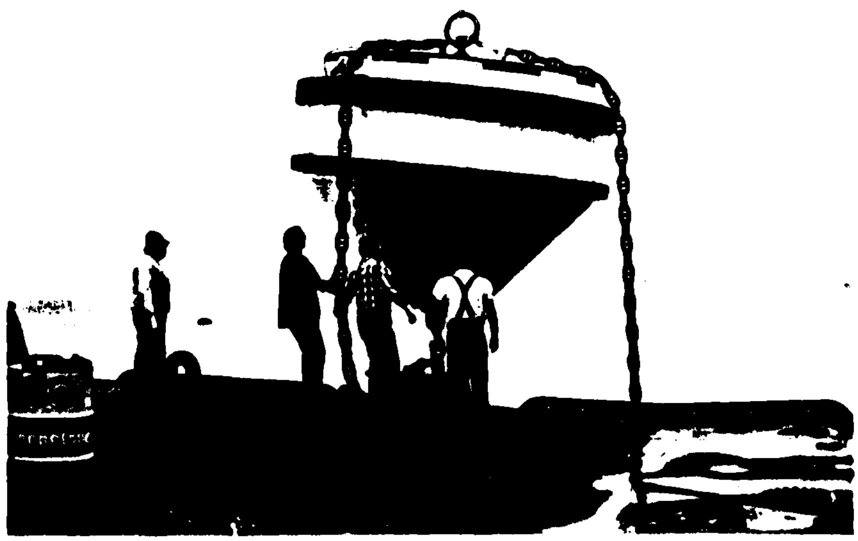


CHAIN STOPPER PLATE REMOVED FROM FE LOWER RISER AND BUOY

FIGURE 4-15

MOORING BUOY #5 BEING LOWERED INTO WATER

FIGURE 4-16



At this point, the first ground leg of the moor, leg A, lay in the approximately correct position along the bottom. The ground ring was on the bottom and the riser chain extended from the ground ring up to the connection at the bottom of the buoy. Two 90-foot lengths of chain, the throw-off legs, ran from the ground ring up to a temporary attachment at the top of the mooring buoy. The next step was to lay the second ground leg.

Leg C was selected as the second ground leg for Mooring Buoy #5 which was to run in a roughly northwesterly direction. The end of the throw-off leg chain was hooked to the crane, detached from the top of the buoy, fed into the FE and locked into place with the forked plate chain stopper. This was referred to as the sixth shot chain for leg C. The fifth shot of chain was picked up by the crane from the YC barge and the end connected with a detachable link to the throw-off leg of chain held in the FE. The chain stopper was then released and the tug pushed the crane barge and cargo barge in the direction of the marker buoys for leg C, feeding out chain through the FE as the barges moved. This movement continued with the fourth, third, second, and first shots of ground leg C being successively connected with detachable links until the anchor end of the first shot was locked in place in the FE.

At this point, the anchor was transferred from the YC to the deck of the crane barge. Attached to it were the wire rope sling, the crown line, and a few links of chain shackled to the end of the anchor shank.

The crown buoy end of the crown line was stoppered off to the deck, Figure 4-17, and a cripple was clamped to the crown line, Figure 4-18. This was a short wire rope with a loop spliced in one end.

Next, the end of the first shot of ground leg chain was connected by a detachable link to the link on the anchor. Using the hook on the crane boom attached to the loop of the cripple, the anchor could then be raised, Figure 4-19, to the point where the load on the end of the first shot of chain was released, the chain stopper disengaged, and the FE opened to allow the chain to swing outboard. The anchor was then lowered to the bottom with the crown line running through the FE to guide it during the lowering.

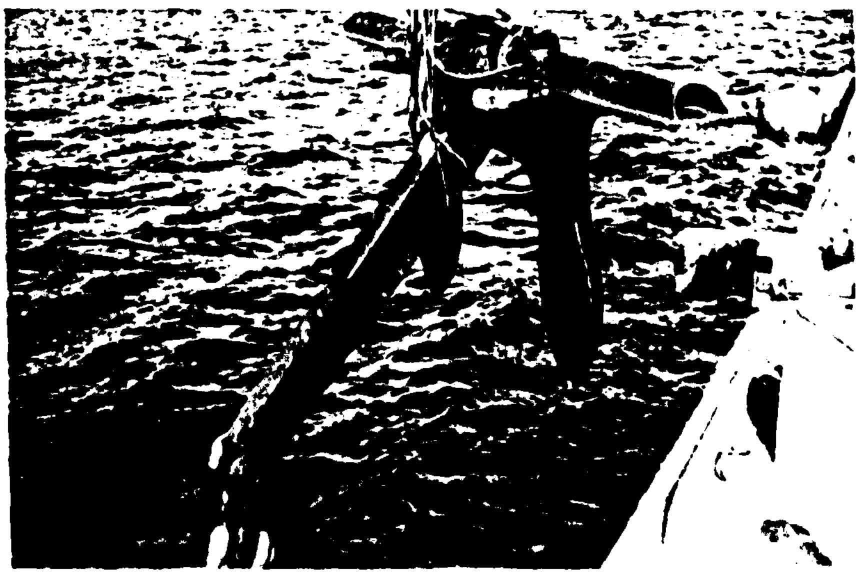
As the anchor neared the bottom, the crane barge was maneuvered so as to line up the crown line with the two marker buoys and to position the FE over the prescribed location for the leg C anchor. The anchor was then

CROWN BUOY END OF CROWN LINE STOPPERED–OFF ON DECK

FIGURE 4–17

CRIPPLE CLAMPED TO CROWN LINE – LEG C

FIGURE 4–18



LOWERING THE 9000 POUND ANCHOR FOR LEG C, MOORING #5

FIGURE 4–19

lowered to the bottom and the crown buoy was connected to the end of the crown line. The crown line was released with some difficulty from the FE. The cripple was then released from the crane hook and the crown buoy was pushed overboard. This completed the installation of the second leg, leg C, at 1530 on 23 August.

The tug then proceeded to push the cargo barge and the crane barge back to the Mooring Buoy #5 to pick up the end of the throw-off chain for leg B. The chain end was inserted in the FE and the chain stopper forked plate installed. As the crane barge was moved south toward the marker buoys, the crane progressively picked up shots of chain from the YC which were connected with detachable links and lowered to the bottom as the crane barge progressed toward the anchor point. The fifth, fourth, third, and second shots were laid along the bottom with the end of the first shot terminating in the FE. The tug pulled on ground leg B to remove all ground leg slack.

The anchor, with bridle and crown line attached, and the crown buoy were moved over from the cargo barge to the crane barge deck. Because of some of the difficulties experienced with the first leg, it was decided to use a slightly different technique for implanting the leg B anchor. A wire rope sheave was hung on one crane hook and the crown line was fed through the sheave, Figure 4-20, and stoppered off on the deck of the crane barge.

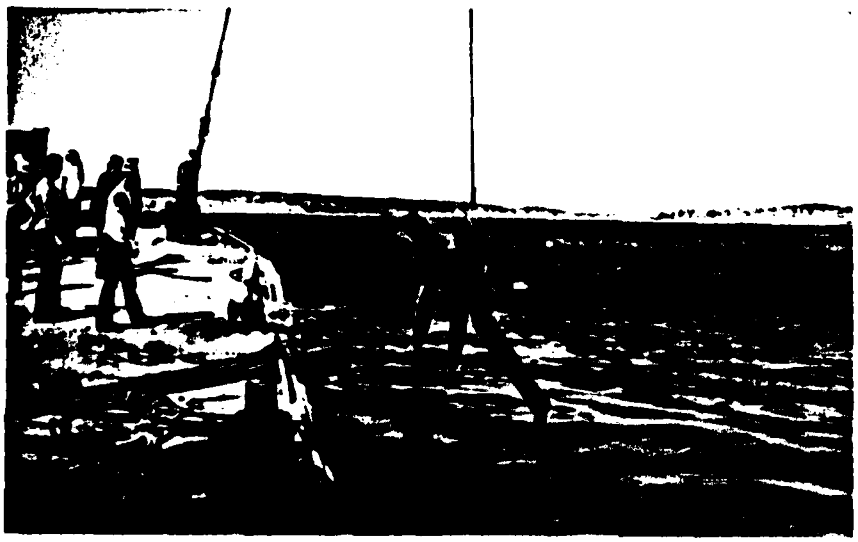
The anchor was secured to the first shot of ground leg B with a detachable link. When the sheave was raised by the crane, the crown line became taut between its point of attachment on the deck, over the sheave, and back down to the bridle on the anchor. With the load lifted off the end links of the first shot of chain, the chain stopper could be removed, the FE opened, and the anchor swung clear of the side of the ship as illustrated in Figure 4-21.

When the anchor reached bottom, the tug applied tension to pull the leg taut. Then the sheave was opened to release the crown line. The stopper connecting the crown line could then be detached from the crane barge deck and the crown line connected to the crown buoy, Figure 4-22. The buoy was then pushed overboard to complete the installation of Mooring Buoy #5 at 1835 on 23 August 1983 and all vessels returned to the pier.

On 25 August at 1055, the crane barge was towed out to Mooring Buoy #5 to shorten the riser. The transit readings from Cliff and Walan indicated

WIRE ROPE SHEAVE
USED ON LEG B TO
LOWER ANCHOR

FIGURE 4-20



LEG B ANCHOR BEING
LOWERED WITH CROWN
LINE RUNNING IN SHEAVE

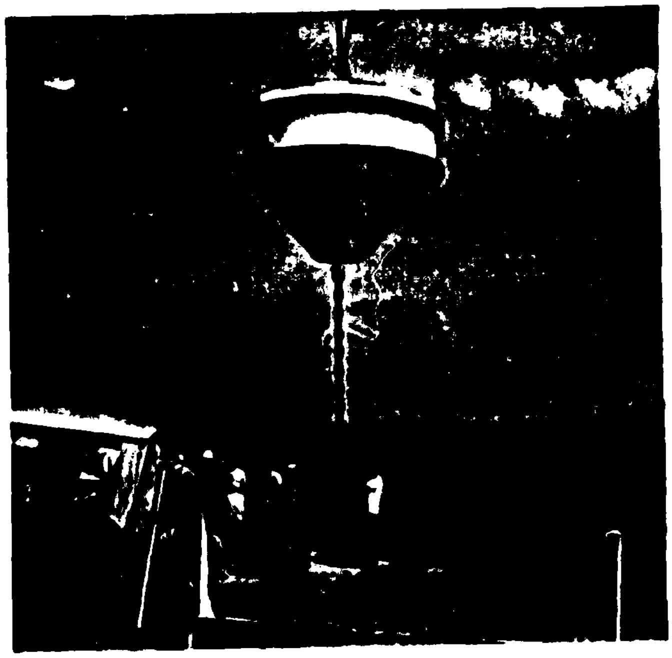
FIGURE 4-21

CONNECTING CROWN LINE
TO CROWN BUOY PRIOR
TO OVERBOARDING BUOY

FIGURE 4-22

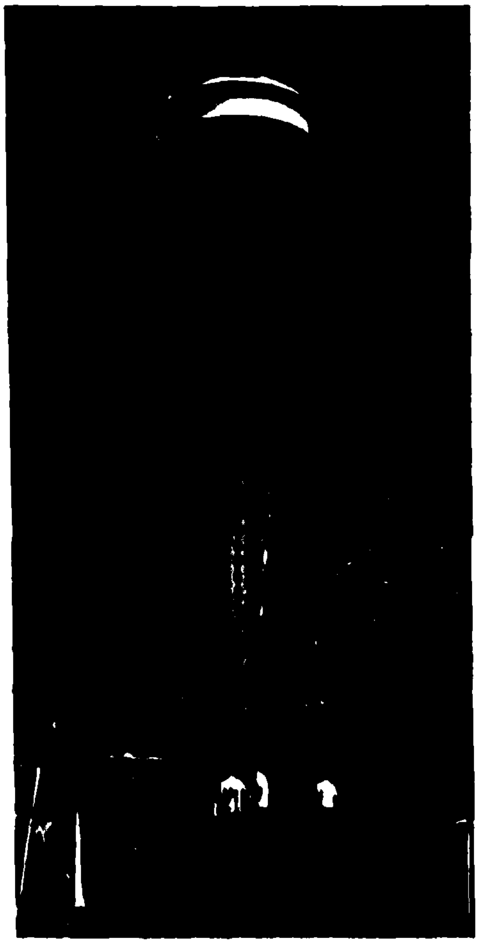
that the buoy was 63 feet northwest of the desired location which was within tolerable limits. Using the big hook on the crane barge, the buoy was lifted clear of the water to a height sufficient to remove the prescribed amount of chain, Figure 4-23. After swinging the chain into the Finger Eater, the FE was closed and the chain stopper inserted. The removable section was originally rigged with two detachable links in which the pins were neither welded nor peened over. To open the links, the pins could be driven out so that no cutting of the chain was required. A detachable link was removed from the riser chain and the buoy gradually lowered with the excess chain piling up on the crane barge deck, Figure 4-24. At the calculated point, the removable section of the riser chain was taken out and the detachable link reinserted, Figure 4-25. As the load was lifted on the crane hook, the FE was opened, and the buoy swung outboard and lowered into the water. During the operation, sights were taken from Walan and Cliff to fix the position of the riser under tension. This operation was completed at 1200 and the crane barge returned to the pier.

The final operation to be conducted on Mooring Buoy #5 was the pull test. The 100-foot tug was rigged with tow rope and dynamometer to conduct these tests, Figure 4-26, and transit operators were stationed at Walan and Cliff. At 1430 on 25 August, the tug was secured to the mooring buoy, Figure 4-27, and it worked up to the prescribed 12,000-pound loading in six directions. Figure 4-28, taken at 1505, shows the pull being applied to the buoy. For each direction of pull, simultaneous transit readings were taken to determine the maximum excursion of the mooring buoy. At the conclusion of the pull tests, when the towrope had been disconnected and the tug moved out of the area, the final transit readings were taken on Mooring Buoy #5 and on the three crown buoys to determine the final location of the buoy and its anchors. These results are plotted on the Washington State Lambert North Zone Coordinates in Figure 4-29.



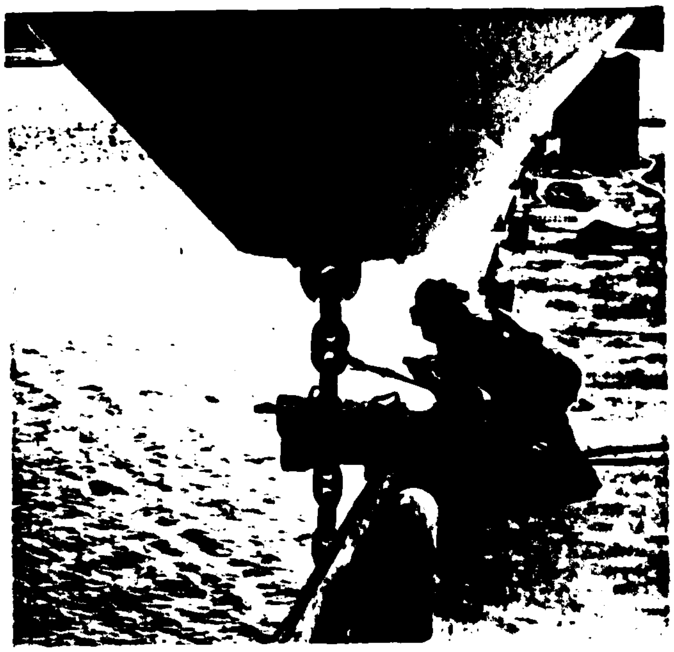
LOWERING EXCESS RISER CHAIN
ON TO CRANE BARGE DECK

FIGURE 4-24



RAISING GROUND RING
BY LIFTING BUOY AND
RISER CHAIN

FIGURE 4-23

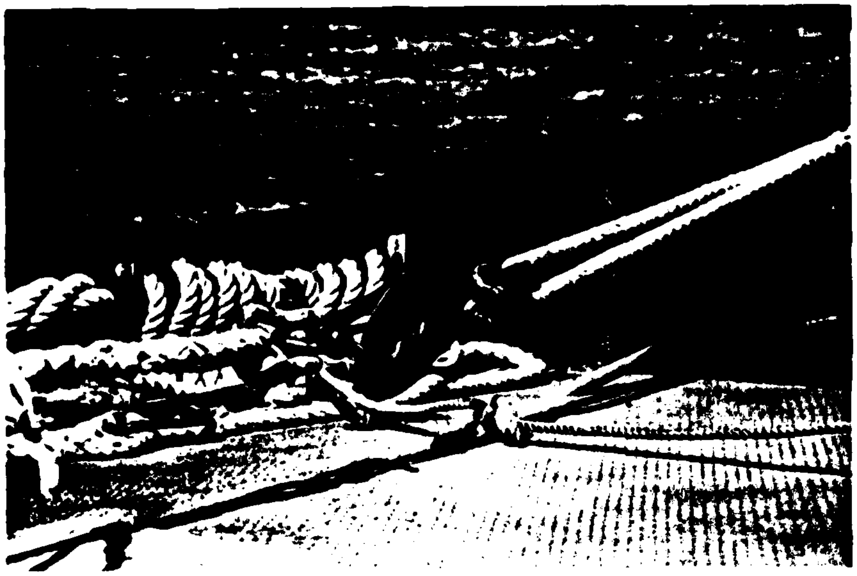


WELDING PIN OF DETACHABLE
LINK AFTER SHORTENING RISER

FIGURE 4-25

RIGGING DYNAMOMETER
FOR PULL TEST ON
MOORING BUOY #5

FIGURE 4-26

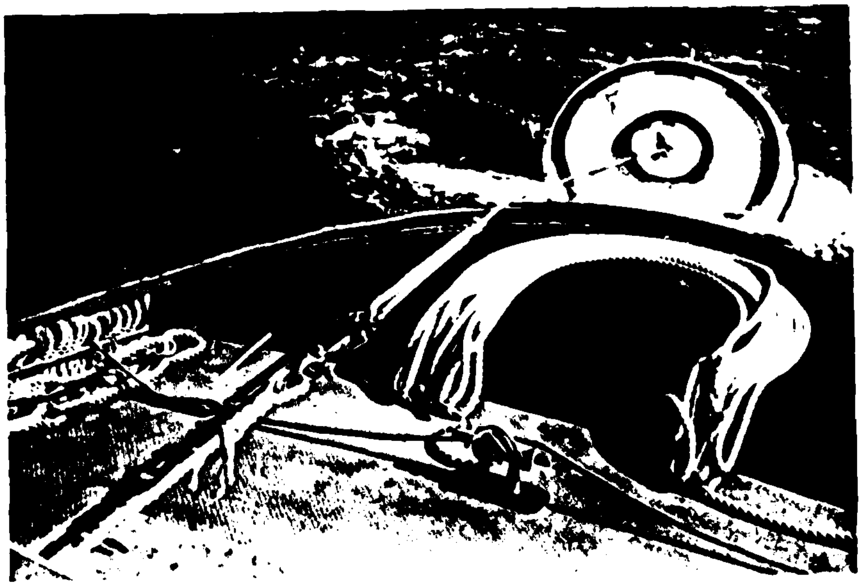


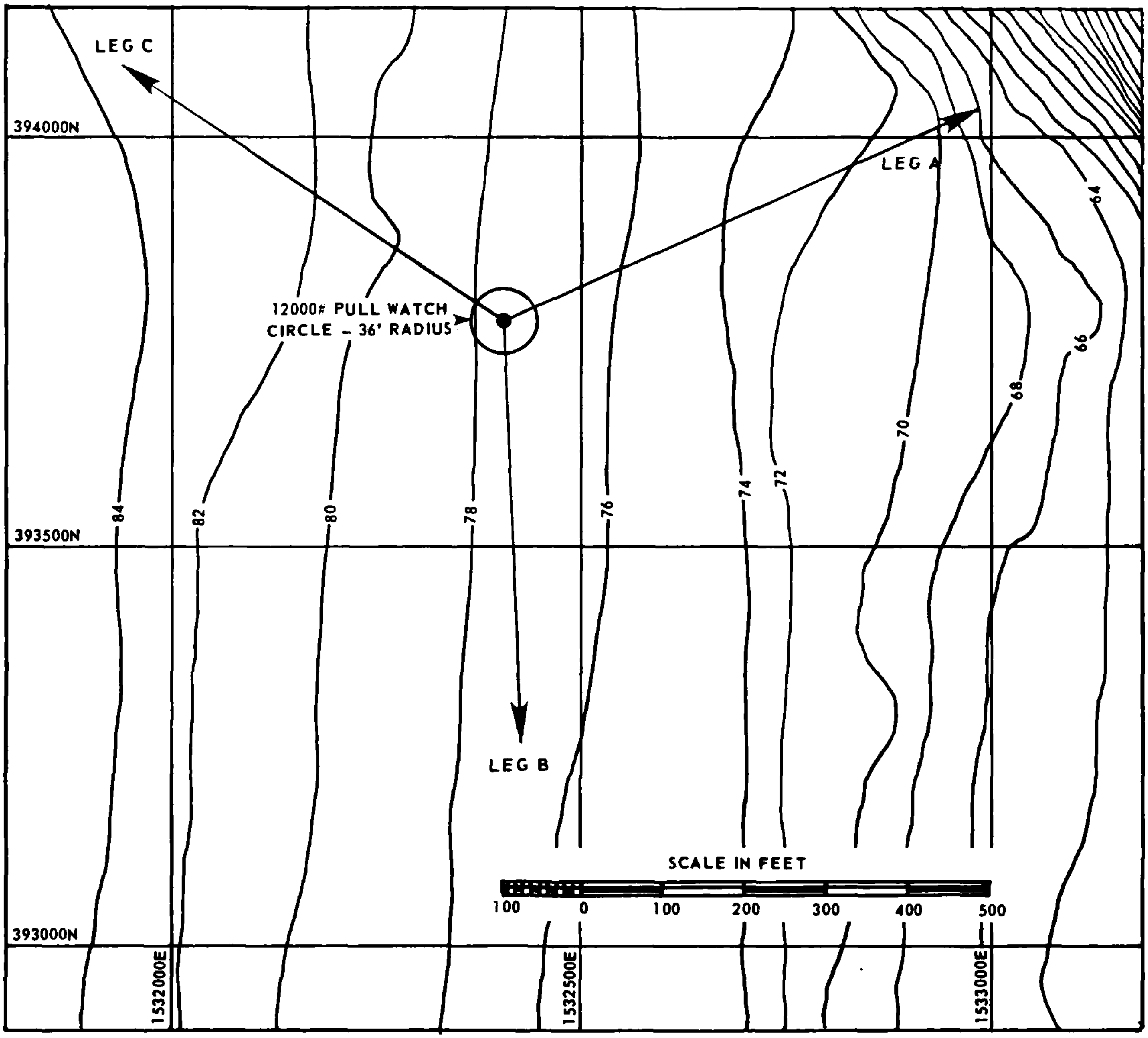
TOW ROPE RIGGED OVER
STERN TO MOORING
BUOY-APPLYING TENSION
TO DYNAMOMETER

FIGURE 4-27

MOORING BUOY #5
UNDERGOING PULL TEST

FIGURE 4-28





FINAL LOCATION OF MOORING BUOY #5 RELATIVE TO
WASHINGTON STATE LAMBERT NORTH ZONE COORDINATES

FIGURE 4-29

INSTALLATION OF MOORING BUOY #4

The second mooring buoy to be installed was #4. The BD crane barge, YC storage barge, and the large and small tugs departed the pier for this installation on 26 August at 0800. By 0910, the first anchor, that for leg A, had been lowered and by 0940 the crown buoy had been installed using the same technique as employed in the previous installation of Mooring Buoy #5. When the anchor and crown buoy installation was completed, the first shot of ground leg chain was suspended from the FE.

To lay ground leg A, the crane picked up the second shot of ground leg chain from the YC barge and connected it to the first shot with a detachable link. The second shot was then lowered through the FE and successive shots of chain were then connected and lowered until the end of the sixth shot of ground leg A approached the FE. As the ground leg was lowered, the tugs had been moving the barges toward the marker that designated the planned location of Buoy #4. The chain-stopper plate was then inserted in the FE. A hard pull was exerted by the tug to straighten out ground leg A after which the crane picked up Mooring Buoy #4, with the riser chain and ground ring suspended from it.

The ground ring was next attached to leg A with a detachable link and the ground ring was lowered to the bottom. Mooring Buoy #4 was in the water by 1111 on 26 August. At 1130 the second leg throw-off was disconnected from the top of the buoy and brought aboard the crane barge.

Shots of chain were successively attached and lowered as the tugs and barges moved in the direction of the marker buoys for leg C. When the last shot had been lowered through the FE, the anchor was connected to the bitter end and readied for lowering. On this anchor, the crown line was again fed through a sheave and the anchor lowered as depicted earlier in Figures 4-20 and 4-21 with the crown line not running through the FE. By 1325, the anchor was on the bottom and the crown buoy had been moved into position on the crane barge deck for attachment to the crown line and, at 1340, the crown buoy was lowered into the water.

At 1415, leg C crown buoy was picked up to apply tension on the leg in order to straighten it out but the pennant broke under the applied load. A second try at tensioning was made at 1440 but this time the wire rope twisted excessively. After sightings from the two transits at Walan and Cliff indicated that the buoy was only 15 feet off location, it was decided to proceed with the laying of leg B. The end of the throw-off leg was picked up from the mooring buoy at 1500 and, using the same technique as for leg C, the ground chain was laid, the anchor connected and lowered, and the crown buoy attached to the crown line. Operations on Mooring Buoy #4 were terminated for the day, 26 August, and at 1700, the tugs and barges headed for the pier.

On the following day, transit sightings indicated that the position of the crown buoy for leg C was questionable so the dive boat was sent out to

install a peanut float at the planned location. At 0845 on 27 August, the tugs and crane barge returned the mooring number 4 location, raised the leg C anchor by the crown buoy, and lowered it again at the prescribed location. The barge was then moved over to the leg B crown buoy, picked up the buoy, and applied tension to leg B to tighten up the system. This completed, the tugs and the crane barge returned to the pier.

Shortly after noon on 27 August, the 100-foot tug and the crane barge left the pier to shorten the riser on Mooring Buoy #4. At 1237, the buoy was lifted from the water and a length of 45 feet was removed from the riser chain. After being lowered back into the water, the buoy floated with considerably greater freeboard, Figure 4-30, than had been the case with Mooring Buoy #5. The 100-foot tug then towed the crane barge back to the pier and returned alone at 1300 to conduct the pull tests.

The dynamometer was rigged aboard the tug as for the first pull test, Figure 4-31. Winds picked up considerably while the pull test gear was being rigged. As the test got underway, the strength of the 1/2-inch towing wire bridle was exceeded and the wire parted, destroying the dynamometer and snapping it overboard, Figure 4-32. At 1500, the tug returned to the pier.

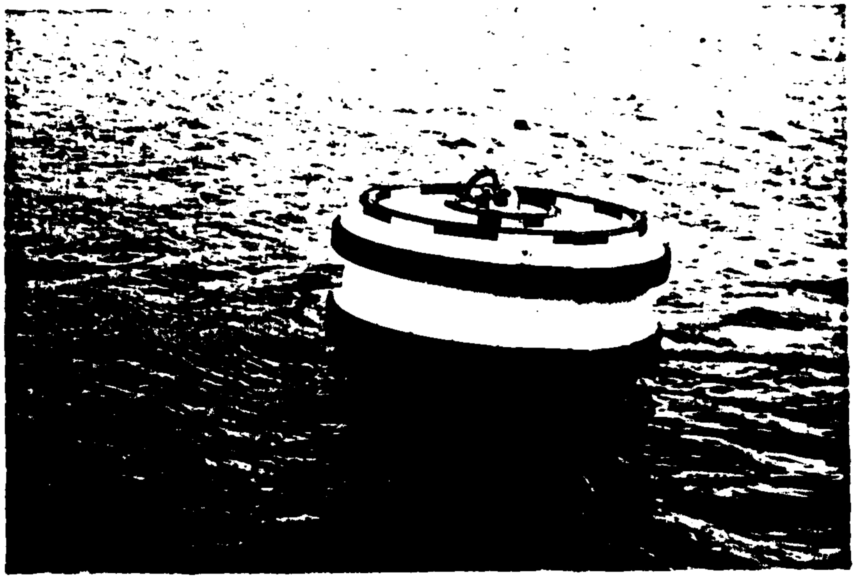
A replacement dynamometer was obtained from the Puget Sound Naval Shipyard. At 1500 on 29 August, the large tug headed back out for Mooring Buoy #4 to attempt once again to conduct a pull test. A heavier pennant (1 inch wire rope) was used for the bridle and the test was conducted without incident. However, all radial buoy movements exceeded specified values.

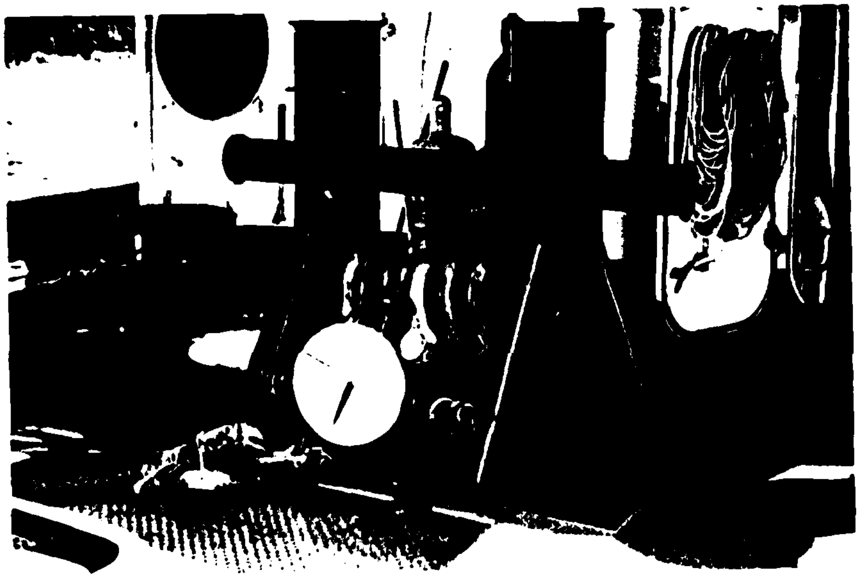
The next opportunity to work on Mooring Buoy #4 occurred on 31 August. At 1450 on that date, the crane barge was towed out to the mooring and the mooring buoy was lifted out of the water to extend the riser back to its original length. After extending the riser and lowering the buoy back into the water, the tug and crane barge moved over to the crown buoy of leg C. Using a nylon line secured to the crown line, the tug pulled on the crown line up to the point where the nylon line parted. It was then assumed that the mooring number 4 system had been stretched out to its maximum.

On the following day, 1 September, the riser was again shortened, and the large tug, returned at 0950 for the pull test. The pull test was satisfactorily completed by 1050 and the tug returned to the pier. The final position of the anchors and buoy, together with the pull test results, are plotted in the Washington State Lambert North Zone Coordinates in Figure 4-33.

MOORING BUOY #4 AFTER
SHORTENING OF RISER

FIGURE 4-30



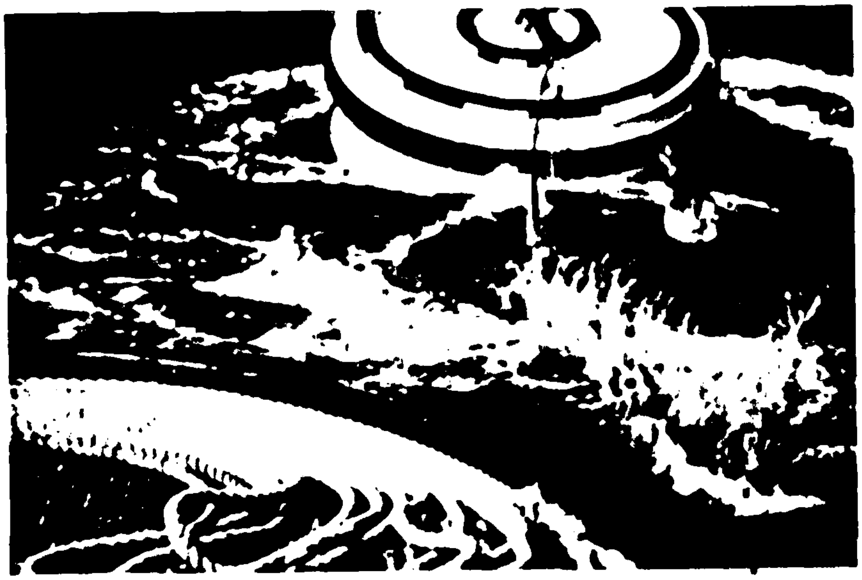


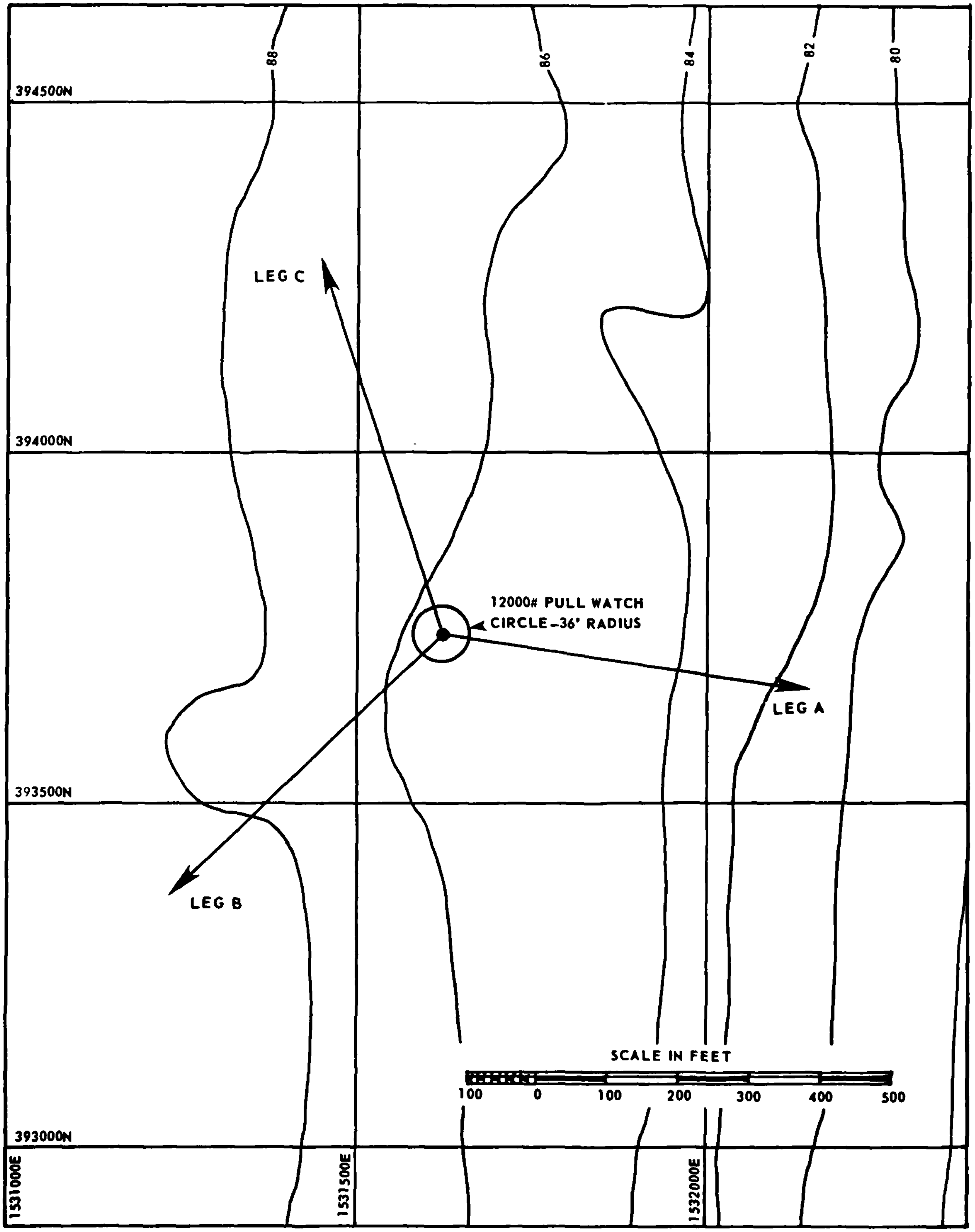
DYNAMOMETER RIGGED FOR
FIRST PULL TEST ON
MOORING BUOY #4

FIGURE 4-31

DYNAMOMETER OVERBOARD AFTER
PARTING OF TOWING LINE

FIGURE 4-32





FINAL LOCATION OF MOORING BUOY #4 RELATIVE TO
WASHINGTON STATE LAMBERT NORTH ZONE COORDINATES

FIGURE 4-33

RETRIEVAL AND REINSTALLATION OF MOORING BUOY #1

Retrieval of mooring number 1 began on 24 August. At 0900, the tugs, the BD crane barge, and the YC storage barge left the pier and by 0948 the crane hook was attached to the #1 buoy. The entire buoy and riser were elevated so that the ground ring could be pulled aboard the barge. It was found that two of the ground legs were taut but the third was slack. The slack leg was disconnected from the ground ring and secured on deck while the buoy, riser, and the other two leg ends were put back in the water.

Using the FE, the detached ground leg was hauled aboard with each shot being disconnected and placed aboard the storage barge. When the last shot of ground leg chain was reached, the anchor was lifted aboard and it too was stowed on the YC. The barges were then towed back to the buoy for recovery of the second leg.

As before, the buoy was raised, the leg detached from the ground ring, the buoy lowered back into the water, and the second ground leg stowed on board the YC, shot by shot. When the anchor for this leg was recovered on board, it appeared that the rigging arrangement had slipped upside down. This could have accounted for its lack of holding power.

The crane barge was then towed back to the mooring buoy. The buoy, the riser, and the third leg and anchor were all recovered on board and at 1700 the crane barge and tug returned to the pier with the retrieval completed.

On 29 August, the two tugs, the BD crane barge, and the YC storage barge once again left the pier for the reinstallation of Mooring Buoy #1. The components of the replacement mooring were those that had been retrieved on 24 August except for the three replacement 25000 pound anchors, miscellaneous connecting links, and the riser extension. By 0900, this fleet was on station with the anchor for leg B suspended over the side and with the crown line and the first shot of chain secured to it; the end of the chain hung in the FE. At 0955, the anchor had been lowered to the bottom and at 1010, the crown buoy was attached to the crown line and in the water. The end of the first shot of ground leg B chain was secured in the FE. Then, as additional shots of chain were connected and lowered, the crane barge was moved toward the mooring buoy location marker.

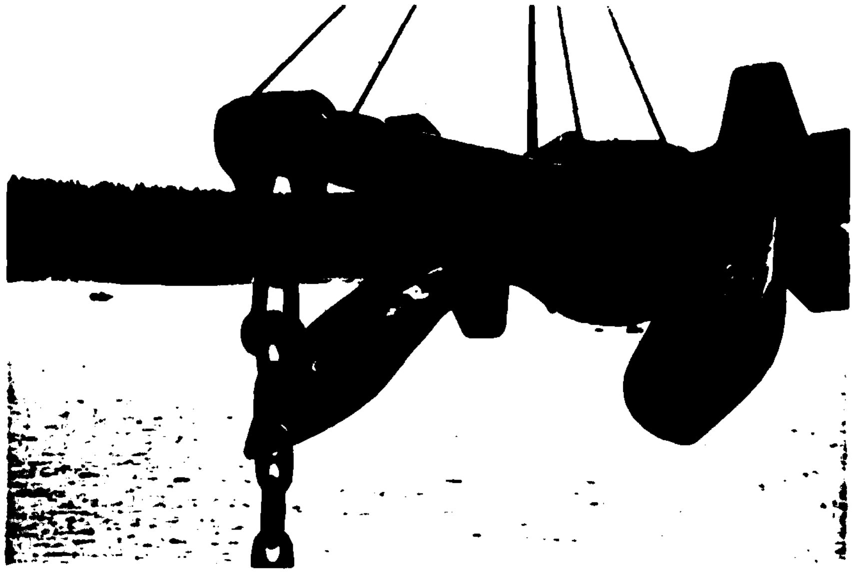
The end of the chain on this leg was connected to the ground ring and Mooring Buoy #1 was lowered into the water. At this point, the end of the first shot of chain for leg A hung in the FE and the end of the first shot of chain for leg C was secured to the top of the buoy.

At 1155, the laying of ground leg A commenced with shots of chain being added and lowered through the FE as the tugs and barges moved toward the leg A anchor location markers. With the end of the last shot of ground leg chain secured in the FE, the anchor was moved across the deck and connected to it. The crown line was fitted through a sheave and the end secured to a forward bitt on the crane barge deck.

Using the big hook on the crane, the sheave was then raised up to the point where the anchor lifted clear of the deck. At this point, with the chain still secured in the FE, the crane barge was pushed forward to straighten out leg A and to move the mooring buoy 25 to 50 feet northward. The crane next lifted the sheave to relieve the chain load on the chain stopper; the stopper was removed and the FE opened. The crane was then boomed out and the load hoisted to move the chain and anchor clear of the FE and of the deck edge and approximately above the prescribed position for the leg A anchor.

It is important that the configuration of the hoisting rigging at this time be clearly depicted. The 25000 pound anchor was suspended over the starboard side of the crane barge, as shown in Figure 4-34, with the last shot of ground leg chain running from the anchor shackle straight down to the bottom in a water depth of about 90 feet. The sling arrangement connecting the anchor to the crown line was such that the anchor shank was horizontal with this load distribution. The crown line ran vertically upward, over a sheave, and then ran forward, down, and inboard to a bitt on the foredeck of the crane barge. The sheave, in turn, was suspended from the main hook of the crane. The load on this hook would have been a vertical downward force equal to twice the weight of the anchor and chain and a horizontal component acting at roughly a right angle to the boom imposed by the forward and inboard run of the crown line to the bitt. This angular relationship can be seen in Figure 4-35. Here the sheave is behind the smaller hook on the crane boom.

When lowering of the anchor started at 1350, a sharp drop of the load occurred as the wire rope ran off two of the sheaves in the travelling block and wrapped around the axle. This significant drop gave rise to the concern



LEG A 25000# ANCHOR
SUSPENDED BY CROWN LINE
FROM SHEAVE ON CRANE HOOK

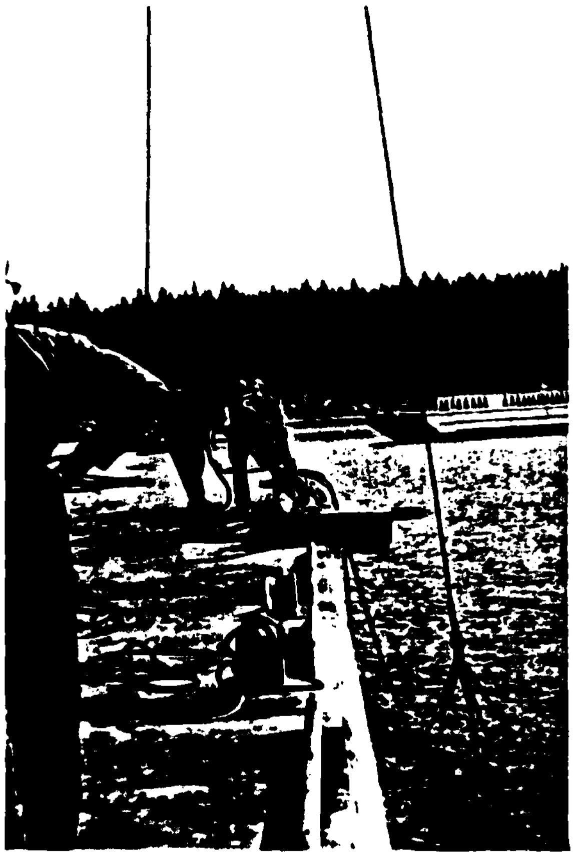
FIGURE 4-34

DAMAGED CRANE BLOCK ASSEMBLY
ANCHOR STILL SUSPENDED

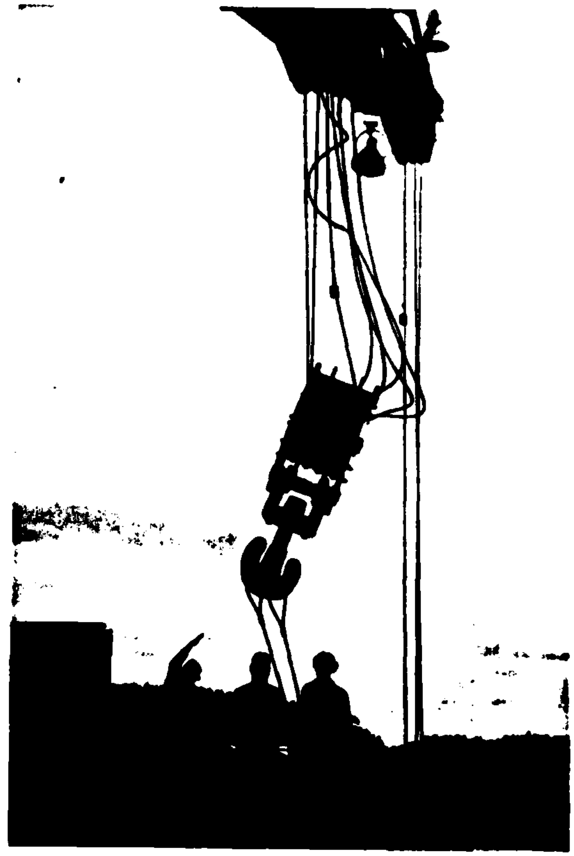
FIGURE 4-35

that the wire rope might part at any moment and therefore steps were taken immediately to relieve the load on the crane hook.

First, the boom was topped down to lower the anchor and chain into the water. A wire was then passed around the crown line above the sling and the crown line was pulled alongside the crane barge. A cripple connection as shown earlier in Figure 4-12, was made to the crown line between the sheave and the water surface with the eye secured on the crane barge deck, Figure 4-36. The crane boom was topped down farther until the cripple took up the load, thus relieving the load on the crane hook. Figure 4-37 shows the hook and tackle system with the load removed.



TRANSFERRING ANCHOR LOAD
FROM CRANE TO DECK EDGE
FIGURE 4-36



CRANE BLOCK ASSEMBLY
WITH LOAD REMOVED
FIGURE 4-37

After this, the sheave was detached from the crane hook and then removed from the crown line. The crown line, at this point, was snubbed up in the middle by the cripple and its end was secured to the forward bitt. A cutting torch was used to cut the cripple and the anchor dropped to the bottom. The crown buoy was next attached to the end of the crown line and overboarded to complete the installation of the leg A anchor. At 1430 on 29 August, the tugs and barges returned to the pier.

On 30 August, the Army BD crane barge was towed to Puget Sound Naval Shipyard for repairs to the damaged rigging. Fortunately, a Navy YD crane barge with operator was available at PSNS to be used as a substitute for the Indian Island mooring project. The Finger Eater was transferred from the BD to the YD and the YD was towed to Indian Island so that operations could be resumed.

At 0930 on 31 August, the 100-foot tug headed out to Mooring Buoy #1, attached to the buoy, and pulled it in the direction of leg C for 3 minutes to realign ground legs A and B. The tug then returned to the pier to pick

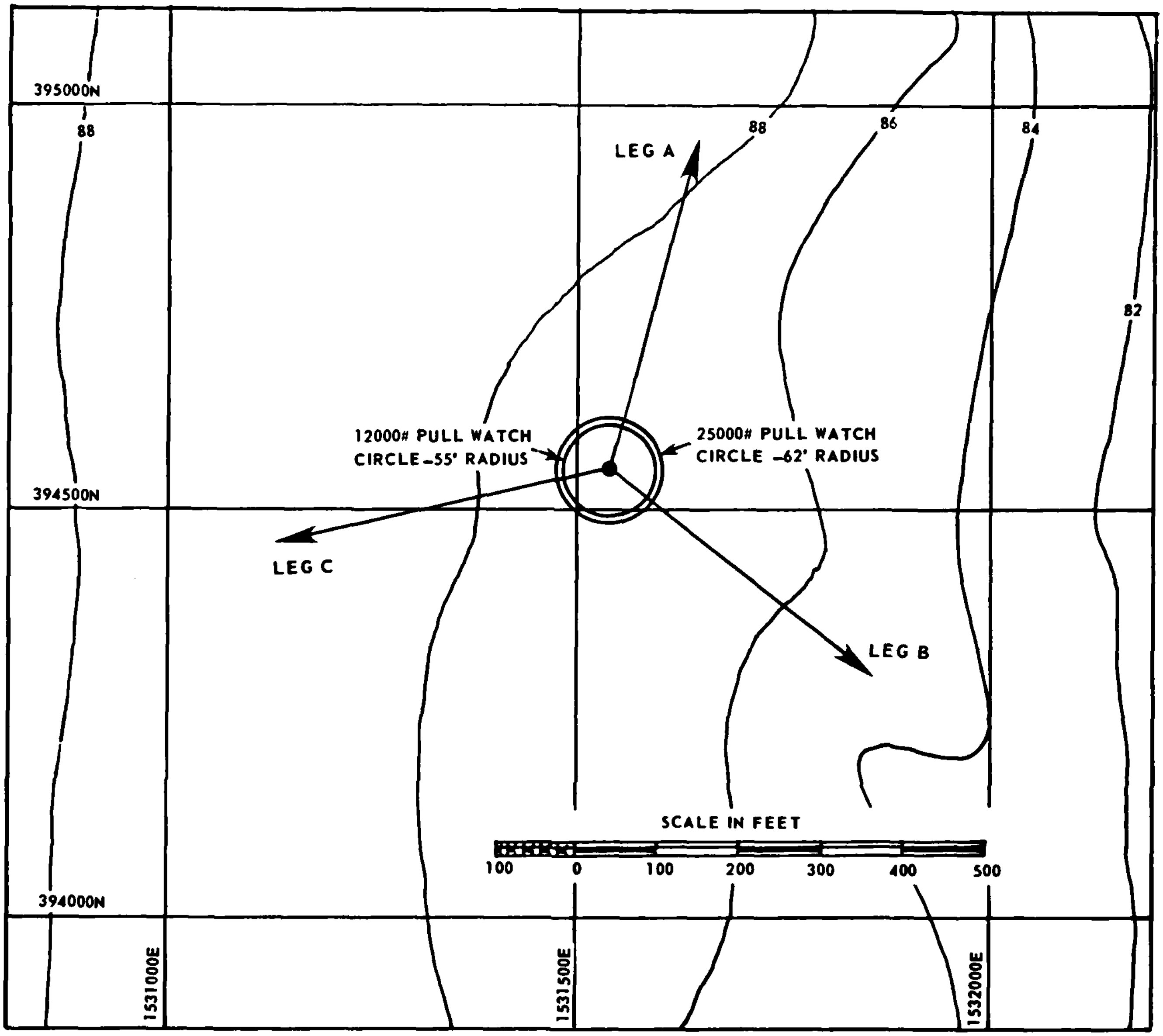
up the YD, the YC, and the small tug and returned to the #1 buoy site to install leg C. At 1130, the throw-off leg was disconnected from the top of the mooring buoy and the laying of leg C proceeded without further incident. The crown buoy went overboard at 1430 and sightings on the crown buoy indicated that some relocation of this anchor was required.

Relocation of the leg C anchor was attempted later in the afternoon of 31 August and again on the morning of 1 September but high winds interferred. This anchor repositioning was finally accomplished after noon on 2 September just prior to shortening the riser.

The buoy initially installed on 29 August was the one that had originally been put in during the Phase I operation in 1978. After retrieval, it had been cleaned of growth. The fenders were found to be worm eaten and rotted, and the metal was rusted. A spare buoy, which had a hawsepipe instead of a tension bar, was taken to the site on 2 September as a replacement.

At 1447 on 2 September, after relocating the leg C anchor, the crane barge was moved over to the mooring buoy. At 1456, the buoy and riser were lifted, the riser stoppered off in the FE, and the removable section taken out. The replacement buoy was then connected to the shortened riser and lowered into the water. At 1530, the vessels returned to the pier.

The 100-foot tug, rigged for the pull test, went back out to Mooring Buoy #1 at 1620. One set of pull tests were conducted with a 12000-pound pull and a second set were conducted with a 25000-pound survivability pull. The results of these pull tests, together with the locations of the buoy and anchors are shown in Figure 4-38.



FINAL LOCATION OF MOORING BUOY #1 RELATIVE TO
WASHINGTON STATE LAMBERT NORTH ZONE COORDINATES

FIGURE 4-38

INSTALLATION OF MOORING BUOY #3

The last mooring buoy to be installed under the Phase II construction operations was number 3. The Navy YD crane barge and YC storage barge and the Army 100-foot tug and 45-foot tug got underway for this operation at 0815 on 2 September 1983. At 0853, the first anchor with the first shot of ground leg A attached was in the water and by 0910 the anchor was on the bottom with the end of the first shot of chain in the FE. The first ground leg was laid without incident and the end of the last shot was connected to the ground ring with the buoy and riser suspended from the crane hook above the FE.

At 1015, the load of ground leg A was transferred from the FE to the

crane and the buoy lowered into the water where the end of the throw-off leg of leg B could be disconnected from the top of the buoy and stoppered off in the FE. The tugs then moved the barges toward the anchor position for leg B as shots of chain were added. At 1103, the leg B anchor was attached to the end of the ground leg and lowered to the bottom.

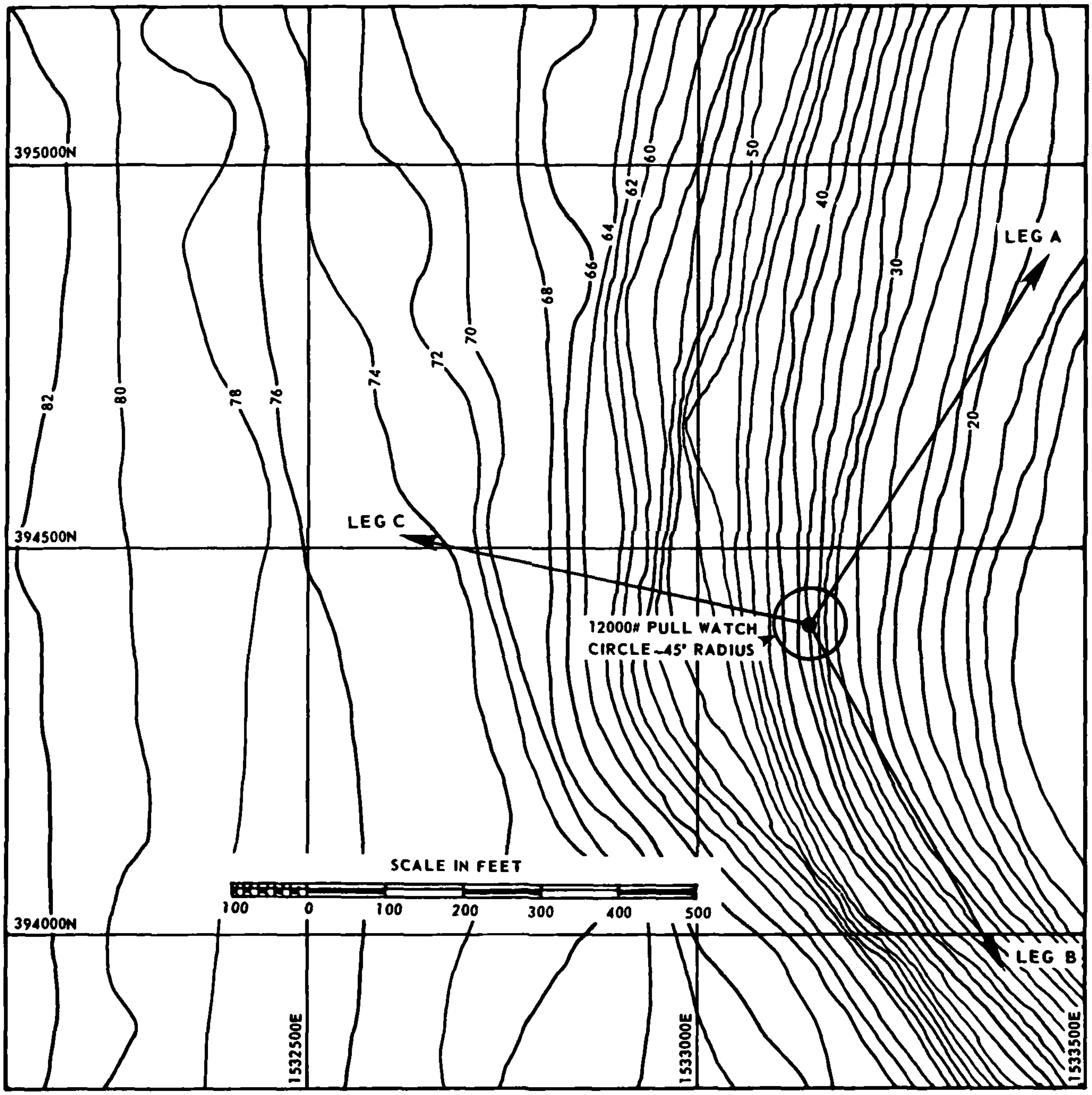
The fleet then moved back to the mooring buoy to pick up the throw-off leg of leg C. This first shot of chain was disconnected from the top of the mooring buoy and stoppered off in the FE. At 1150, the YD was pushed toward the leg C anchor position to remove slack from legs A and B. The laying of the third leg started at noon. At 1235, anchor and crown line were attached to leg C and a pull was applied in a westward direction to tighten up all three ground legs. At 1330, the anchor was lowered and the crown buoy attached to the crown line and overboarded. This completed the work on Mooring Buoy #3 for 2 September.

At 0750 on the morning of 3 September, the tug and crane barge left the pier to shorten the riser on the number 3 buoy. The buoy was lifted, a 25-foot section of riser was removed, and the buoy was reconnected and lowered. A diver, sent down to inspect the elevation of the ground ring, reported that it was still on the bottom. At 1000, the buoy was once again picked up and an additonal 12 feet of riser was removed, this being the most that could be taken out without removing the swivel from the riser.

The minimal riser length required for the #3 buoy and the shallow depth of the anchors for legs A and B confirmed an earlier suspicion that something was wrong with the bathymetric data that were used in the Phase II planning. These data had been obtained by a contractor prior to the Phase I operations and comprised a complete set of depth contours for the entire mooring area.

During Phase I there had been a mix-up over the location of a Mini-Ranger transponder at Kala Point which caused the initial location errors noted previously for mooring numbers 1, 2, and 6. Since the same transponder location was used for the bathymetric survey, it is logical to conclude that similar errors may be found in the depth contours. These errors are analyzed in Appendix C of this report and all illustrations involving depth contours herein, except for Figure 2-3, represent the corrected bathymetry.

Returning now to the installation of Mooring Buoy #3, the pull test was conducted starting at 1026 on 3 September and completed at 1107. The results of this pull test, together with locations of the buoy and anchors, are shown in Figure 4-39. This completed the Phase II construction operations.

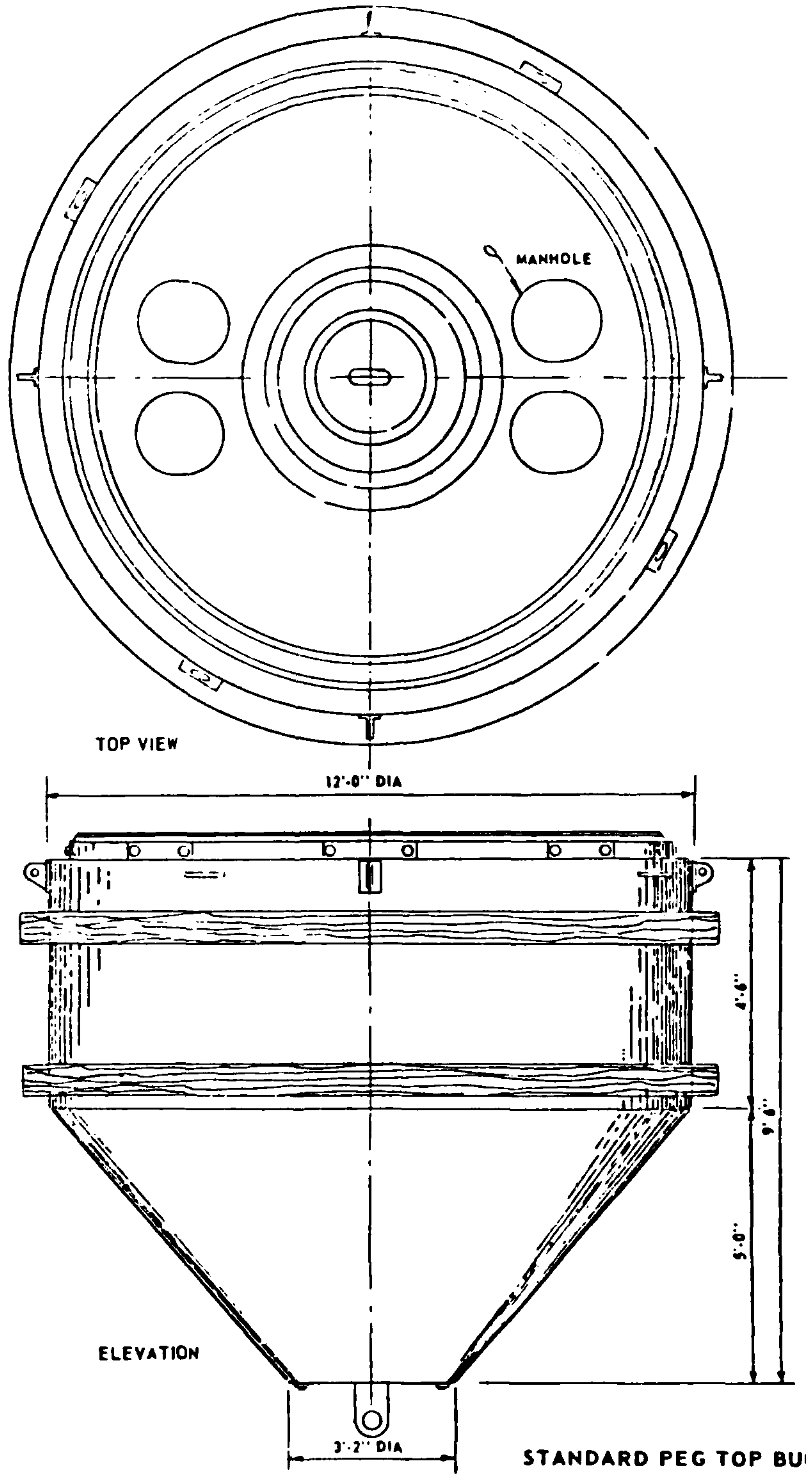


FINAL LOCATION OF MOORING BUOY #3 RELATIVE TO
WASHINGTON STATE LAMBERT NORTH ZONE COORDINATES

FIGURE 4-39

5.0 AS-BUILT CONFIGURATION

The reinstallation of Mooring #1 and the installation of Moorings #3, #4, and #5 was completed on 3 September 1983 as described in the preceding section. Upon completion of each mooring installation, and the sighting-in of the anchor locations, the crown buoys were removed leaving only the mooring buoys themselves in evidence on the surface. The configuration of a typical mooring buoy is depicted in Figure 5-1.



STANDARD PEG TOP BUOY

FIGURE 5-1

LOCATION OF MOORINGS AND ANCHORS

For Moorings #1, #3, #4, and #5, the location of the mooring buoy and anchors have been illustrated by individual plots in the construction operations section of this report together with the corrected bathymetry as it relates to each mooring. In Figure 5-2, the location of all six of the Indian Island moorings is shown on an area chart plotted on the Washington State Lambert North Zone Coordinates. The depth contours are given in feet at mean lower low water and the contour locations have been corrected for the earlier discrepancy caused by the erroneous location of the Kala Point transponder in 1978. The circles around the buoys are scale representations of the buoy movement under the 12000-pound pull test (plus an additional 25000-pound survivability pull test in the case of Buoy #1).

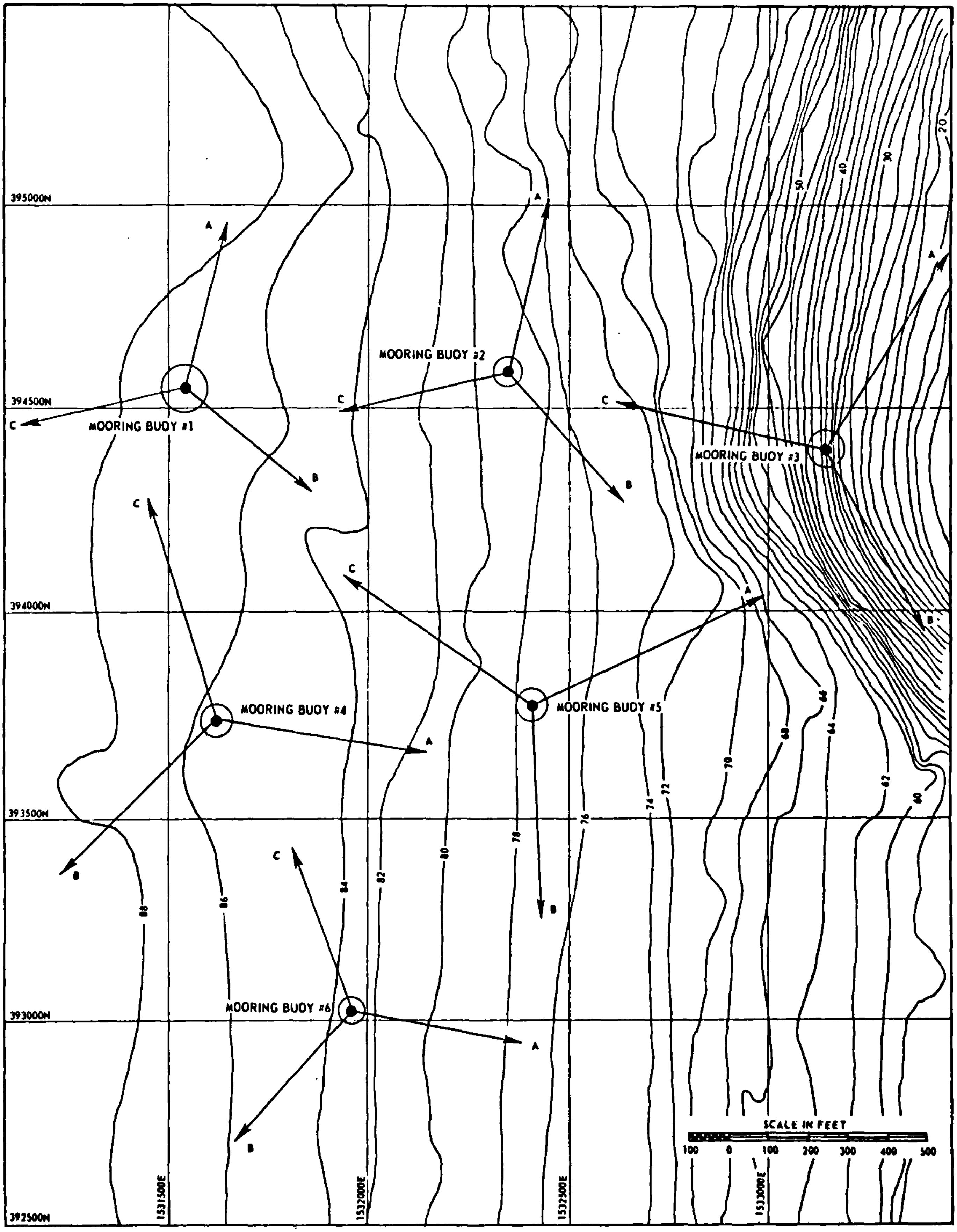
The locations of the mooring buoys, as sighted in by transit from Cliff and Walan, are tabulated below in Washington State Coordinates in feet. The anchor locations shown by the arrow heads on Figure 5-2, and the anchor coordinate tabulation below, are at the last sighted location of the respective crown buoys for these anchors.

INDIAN ISLAND MOORINGS
BUOY AND ANCHOR COORDINATES
WASHINGTON STATE LAMBERT NORTH ZONE

	COORDINATES	
MOORING	NORTH	EAST
BUOY #1	394550	1531550
ANCHOR A	4960	31654
B	4299	31859
C	4460	31138
BUOY #2	394572	1532350
ANCHOR A	4987	32457
B	4279	32643
C	4465	31950
BUOY #3	394407	1533147
ANCHOR A	4891	33449
B	3913	33381
C	4520	32614

	COORDINATES	
MOORING	NORTH	EAST
BUOY #4	393750	1531621
ANCHOR A	3622	32151
B	3327	31317
C	4266	31414
BUOY #5	393784	1532410
ANCHOR A	4044	32990
B	3253	32428
C	4096	31933
BUOY #6	393026	1531963
ANCHOR A	2954	32373
B	2707	31696
C	3417	31821

LOCATION	COORDINATES IN FEET NORTH	EAST
BENCH MARK - CRANE	391485	1534607
BENCH MARK - WALAN	397070	1532462
BENCH MARK - CLIFF	395378	1534593
BENCH MARK - KALA (ACTUAL)	391865	1527416
SMALL CRAFT PIER (AMMUNITION PIER)	397192	1531861
SAW SHED (ESTIMATED)	397545	1532765
MINE SHOP (ESTIMATED)	392136	1534252



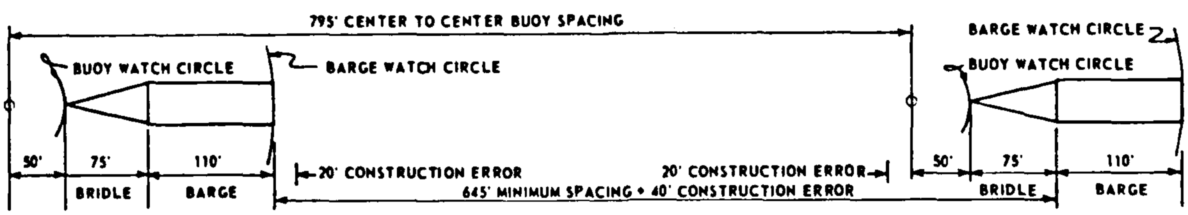
AS-BUILT LOCATIONS OF INDIAN ISLAND MOORINGS RELATIVE TO WASHINGTON STATE LAMBERT NORTH ZONE COORDINATES

FIGURE 5-2

Also given in the foregoing table for ready reference are the Washington State Lambert North Zone Coordinates for the three bench marks used in the course of this project and the three shore points of concern from the standpoint of explosion safety. The saw shed and mine shop locations are undocumented.

Of particular interest with regard to mooring buoy location is the final position of the buoy and the ammunition barge watch circles with respect to the ESQD radii from critical facilities ashore on Indian Island. Each watch circle represents the path of the stern of the barge as it swings around the buoy under a combined wind and current loading of 12000 pounds. The watch circle radius is the sum of the pull test radius plus a 75-foot bridle plus the 110-foot barge length. These radii are 240 feet for Mooring #1, 218 feet for Mooring #2, 230 feet for Mooring #3, 221 feet for Mooring #4, 221 feet for Mooring #5, and 217 feet for Mooring #6.

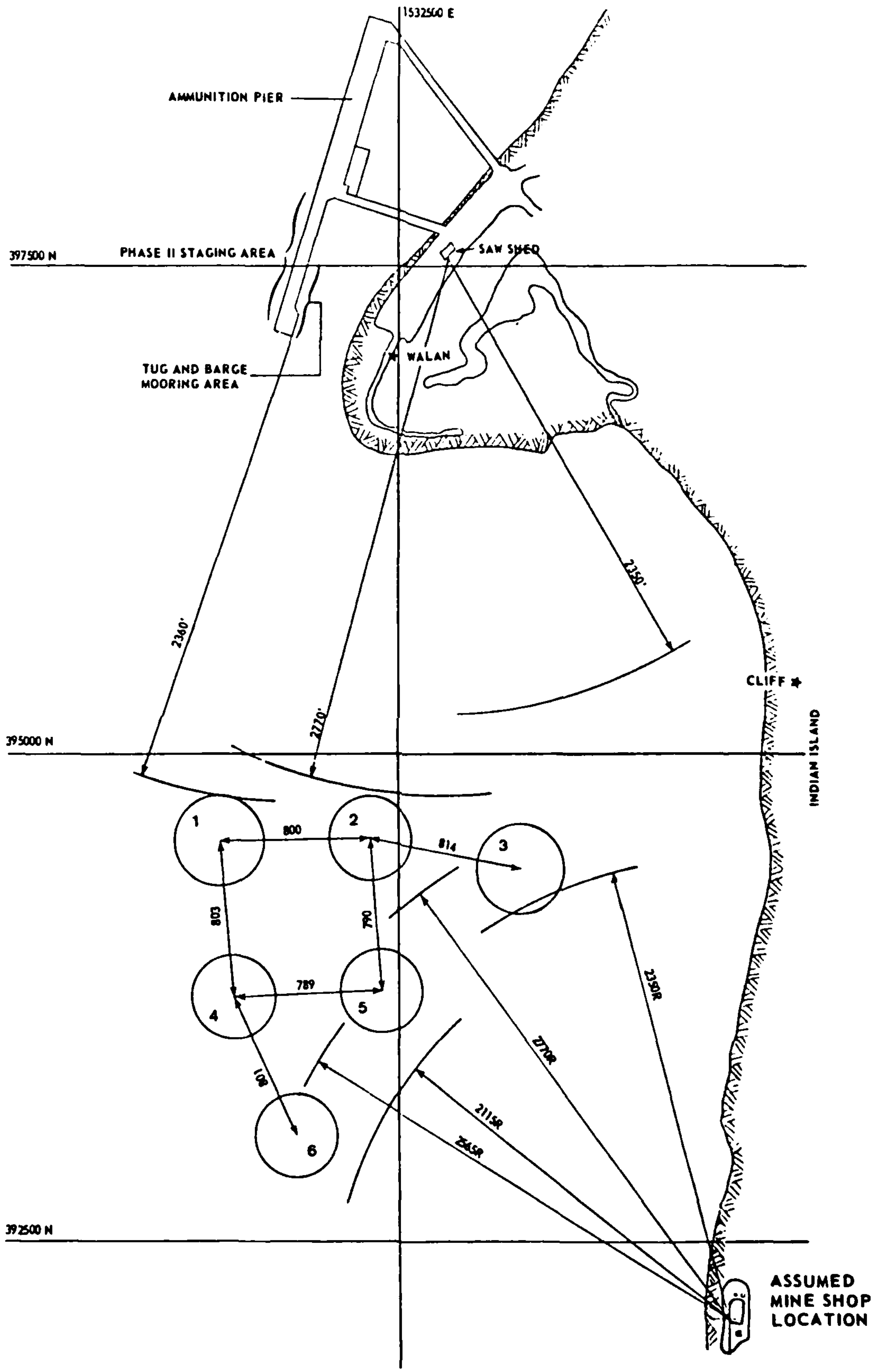
An additional consideration is the barge to barge spacing that must be maintained. For a 200 kip ammunition load this spacing is 645 feet from the stern of one barge to the bow of the next. Figure 5-3 shows how this requirement was translated into the specified mooring buoy spacings given earlier in Figure 2-4; Figure 5-4 shows the comparable actual values of the buoy to buoy spacing and barge watch cirlce to shore point distances that resulted from the Phase I and Phase II installation efforts.



DERIVATION OF MOORING BUOY SPACING FOR A 200 KIP AMMUNITION LOAD

FIGURE 5-3

Note that the *required* 645-foot barge stern to barge bow spacing has been increased by two additive 20-foot construction errors to obtain the *specified* buoy spacing. In comparing the actual buoy spacings with the specified values, these anticipated construction errors may be neglected. In the following table, the corrected buoy to buoy requirements are compared with the spacings actually achieved as are the equivalent barge stern to barge bow spacings when both vessels are hanging downwind from the buoys in the same direction at the minimum spacing angle.



WATCH CIRCLES OF AMMINITION BARGES WITH
RESPECT TO ESQD RADII FROM SHORE FACILITIES

FIGURE 5-4

COMPARISON OF INDIAN ISLAND MOORING BUOY SPACING
WITH INITIAL REQUIREMENTS FOR BARGE SEPARATION

DIMENSIONS IN FEET

BUOY PAIR		BUOY TO BUOY SPACING			MOORING BUOY WATCH CIRCLE RADII		BARGE SPACING STERN TO BOW	
A	B	SPECIFIED	REQUIRED	ACTUAL	R_A	R_B	REQUIRED	ACTUAL
#1	#2	795	755	800	55	33	645	668
#2	#3	795	755	814	33	45	645	692
#1	#4	795	755	803	55	36	645	674
#2	#5	795	755	790	33	36	645	677
#3	#5	735	695	965	45	36	585	846
#4	#5	765	725	789	36	36	615	679
#4	#6	765	725	801	36	32	615	687
#5	#6	700	660	880	36	32	550	766

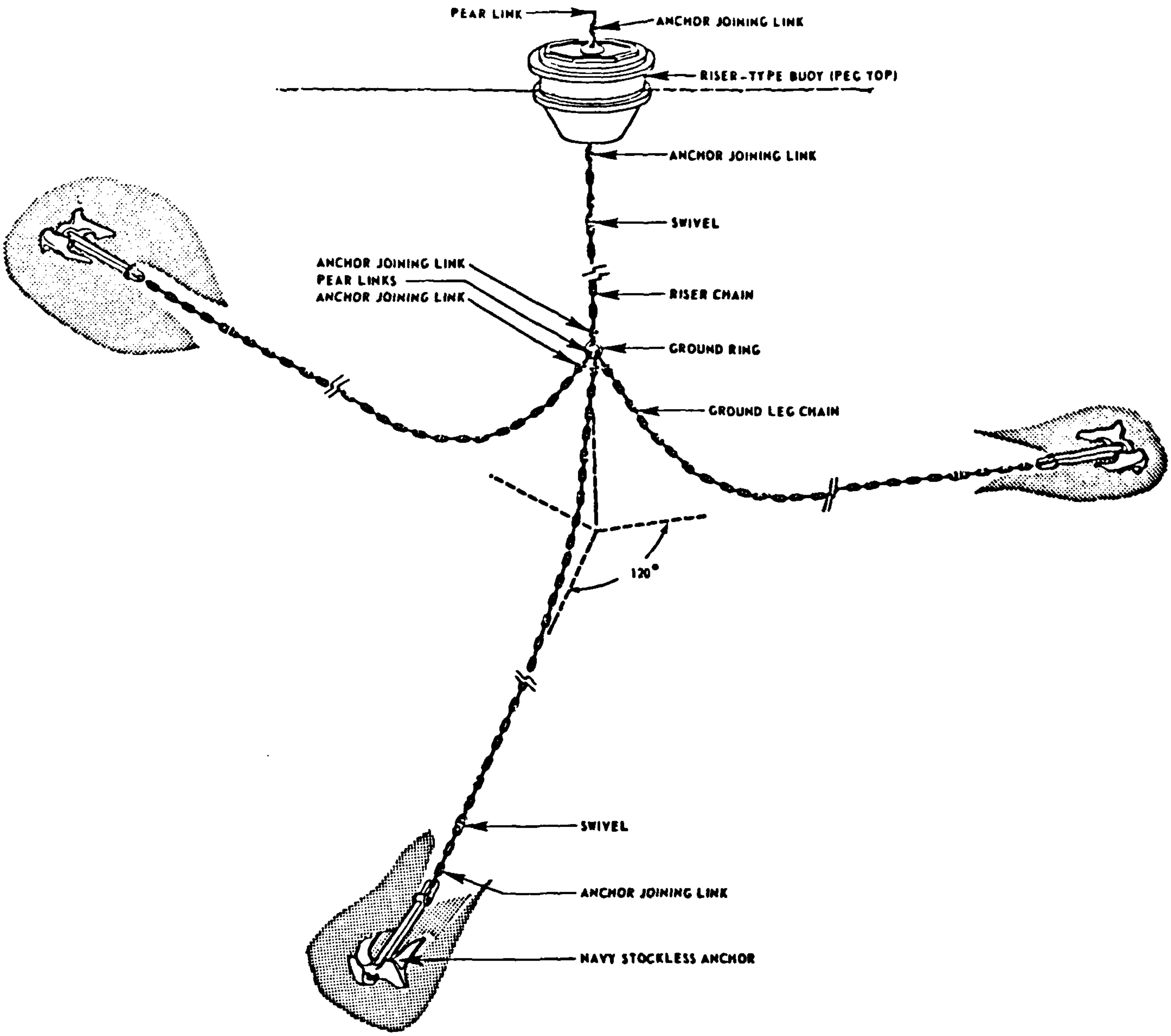
It can be seen from this table that all pairs of buoys were installed with a spacing greater than is required and similarly the barge stern to barge bow spacing also exceeds the minimum requirements.

In Figure 5-4 the watch circles of the ammunition barge sterns are shown in relationship to the specified radii from fixed points on Indian Island, namely the small craft pier at the south end of the ammunition pier, the saw shed on Walan Point, and the mine shop south of the mooring array on the Indian Island shoreline. These specified ESQD radii from shore points were calculated without the allowance for the construction error that was included in the barge spacing calculation. As a result, any overlap of these arcs with the barge stern watch circles represent a failure to meet the mooring location specifications. It can be seen that these locations are met in all cases except for the distance of Mooring Buoy #3 from the mine shop where the watch circle overlaps the 2350-foot arc by 54 feet.

Although the exact location of the mine shop is not certain, it appears that some change in the allowable ammunition load for barges moored to buoy #3 might be in order. The curve of ammunition weight versus distance to cricial shore points indicates that reduction of the load from 150 kips to 144 kips would be required to compensate for the discrepancy in the position of buoy #3. It is therefore recommended that the specified loading for barges moored to this buoy be reduced to 125 kips.

AS-BUILT COMPONENTS OF THE SIX MOORINGS

The general arrangement of the buoys, risers, ground legs, and anchors illustrated in Section 2.0 of this report is repeated in Figure 5-5 for ready reference. Additionally, the data on the components of moorings #2 and #6 given in the Phase I Completion Report [1] are included in a slightly revised



SHORTENED-RISER, FREE-SWINGING MOORING USED AT INDIAN ISLAND

FIGURE 5-5

format for completeness and for direct comparison with the components installed during Phase II.

There are two tabulations given. The first is for mooring numbers 1, 2, and 6 and the second is for mooring numbers 3, 4, and 5. It will be recalled that mooring number 1 is essentially the same as it was in 1979 except that the 20000-pound anchors have been replaced with 25000-pound anchors with stabilizers.

Referring to Figure 5-5, the tabulations of components start with

INDIAN ISLAND MOORINGS
AS-BUILT COMPONENTS
DIMENSIONS IN FEET

RISERS	MOORING :1			MOORING :2			MOORING :6		
BUOY PADEYE	HAWSEPIPE 0.83			0.83			0.83		
3 IN DETACHABLE LINK	1.17 B			1.17 B			1.17 B		
PEAR LINK	1.08			1.08			1.08		
2 1/2 IN DETACHABLE LINK	0.79 B			0.79 B			0.79 B		
2 1/2 IN CHAIN	40.00 ←REMOVED			40.00 ←REMOVED			40.00 ←REMOVED		
2 1/2 IN DETACHABLE LINK	0.79 B ←REMOVED			0.79 B ←REMOVED			0.79 B ←REMOVED		
2 1/2 IN CHAIN	9.21			9.21			9.21		
2 1/2 IN DETACHABLE LINK	0.79 B			0.79 B			0.79 B		
2 1/2 IN SWIVEL	2.38			2.38			2.38		
2 1/2 IN DETACHABLE LINK	0.79 B			0.79 B			0.79 B		
2 1/2 IN CHAIN	21.83			21.83			21.83		
2 1/2 IN DETACHABLE LINK	0.83 C			0.83 C			0.79 B		
4 TO 2 1/2 IN ANCHOR JOINING LINK	1.63 B			1.63 B			1.63 B		
4 IN GROUND RING	0.83			0.83			0.83		
GROUND LEGS	LEG A	LEG B	LEG C	LEG A	LEG B	LEG C	LEG A	LEG B	LEG C
4 TO 2 1/2 IN ANCHOR JOINING LINK	1.63 B	1.63 B	1.63 B	1.63 B	1.63 B	1.63 B	1.63 B	1.63 B	1.63 B
2 1/4 IN DETACHABLE LINK	0.75 B	0.75 N	0.75 B	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN CHAIN	80.00	90.00	90.00	90.00	89.00	89.00	90.00	89.00	90.00
2 1/4 IN DETACHABLE LINK	0.75 N	0.75 N	0.75 N	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN CHAIN	90.00	89.00	90.00	90.00	109.00	89.00	90.00	90.00	90.00
2 1/4 IN DETACHABLE LINK	0.75 N	0.75 N	0.75 N	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN CHAIN	90.00	90.00	90.00	87.00	77.00	90.00	90.00	101.00	85.00
2 1/4 IN DETACHABLE LINK	0.75 B	0.75 N	0.75 B	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN CHAIN	90.00	90.00	90.00	90.00	89.00	91.00	90.00	90.00	90.00
2 1/4 IN DETACHABLE LINK	0.75 N	0.75 N	0.75 B	0.75 C	0.75 C	0.75 N	0.75 B	0.75 B	0.75 B
2 1/4 IN CHAIN	43.00	44.00	43.00	44.00	48.00	45.00	45.00	45.00	45.00
2 1/4 IN DETACHABLE LINK	0.75 N	0.75 N	0.75 B	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN SWIVEL	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14
2 1/4 IN DETACHABLE LINK	0.75 C	0.75 C	0.75 C	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN CHAIN	21.11	22.11	21.11	22.11	22.11	19.11	22.11	22.11	22.11
2 1/4 IN DETACHABLE LINK	0.75 C	0.75 C	0.75 C	0.75 C	0.75 C	0.75 C	0.75 B	0.75 B	0.75 B
2 1/4 IN END LINKS	1.25	2.67	2.00	1.67	-	1.67	0.83	1.00	2.25
BENDING SHACKLE	-	-	-	1.00	1.25	1.00	1.33	1.00	1.00
ANCHOR SHACKLE	1.75	1.75	1.25	1.83	1.67	1.83	2.00	2.00	2.00
ANCHOR WEIGHT - #	25000	25000	25000	18000	18000	18000	18000	18000	18000
— RISER LENGTH - FT		41			41			41	
— GROUND LEG LENGTH - FT	427	439	437	437	447	437	441	451	437
— MLLW DEPTH - FT		88			79			83	

C E. V. CAMP STEEL WORKS
N NATIONAL MALLEABLE AND STEEL CASTINGS CO
B BALDT ANCHOR, CHAIN, AND FORGE COMPANY

the buoy padeye at the bottom of the buoy, approximately 5 feet below the water surface, and then proceed down the riser to the ground ring. Below the ground ring the components of the three ground legs are listed from the ground ring to each anchor shackle.

For each riser and for each ground leg, the component lengths in feet are listed and, where available, the manufacturers are indicated. This is done to facilitate later inspections by helping divers to identify which string of components they are following.

INDIAN ISLAND MOORINGS
AS-BUILT COMPONENTS

DIMENSIONS IN FEET

RISER	MOORING #3			MOORING #4			MOORING #5		
BUOY PADEYE	0.83			0.83			0.83		
2 1/4 IN SHACKLE	0.75			0.75			0.75		
1 3/4 IN DETACHABLE LINK	0.39 B			0.86 C-AJL			0.39 B		
1 3/4 IN CHAIN	25.00 J ← REMOVED			45.00 J ← REMOVED			45.00 J ← REMOVED		
1 3/4 IN DETACHABLE LINK	0.39 B ← REMOVED			0.39 B ← REMOVED			0.39 B ← REMOVED		
1 3/4 IN CHAIN	12.00 J ← REMOVED			8.00 J			9.00 J		
1 3/4 IN DETACHABLE LINK	0.39 B ← REMOVED			0.39 J			0.39 B		
1 3/4 IN SWIVEL SHOT	8.00 J			25.00 J			25.00 J		
1 3/4 IN ANCHOR JOINING LINK	0.86 C			0.86 C			0.86 C		
GROUND RING	0.63			0.63			0.63		
GROUND LEGS	LEG A	LEG B	LEG C	LEG A	LEG B	LEG C	LEG A	LEG B	LEG C
1 3/4 IN ANCHOR JOINING LINK	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C
1 3/4 IN CHAIN	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J
1 3/4 IN DETACHABLE LINK	0.39 B	0.39 B	0.39 B	0.39 B	0.39 B	0.39 B	0.39 B	0.39 B	0.39 B
1 3/4 IN CHAIN	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J
1 3/4 IN DETACHABLE LINK	0.39 B	0.39 B	0.39 B	0.39 J	0.39 J	0.39 J	0.39 J	0.39 J	0.39 J
1 3/4 IN CHAIN	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J
1 3/4 IN DETACHABLE LINK	0.39 B	0.39 B	0.39 B	0.39 J	0.39 J	0.39 J	0.39 J	0.39 J	0.39 J
1 3/4 IN CHAIN	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J
1 3/4 IN DETACHABLE LINK	0.39 B	0.39 B	0.39 B	0.39 J	0.39 J	0.39 J	0.39 J	0.39 J	0.39 J
1 3/4 IN CHAIN	65.00 J	65.00 J	65.00 J	65.00 J	65.00 J	65.00 J	65.00 J	65.00 J	65.00 J
1 3/4 IN DETACHABLE LINK	0.39 B	0.39 B	0.39 B	0.39 J	0.39 J	0.39 J	0.39 J	0.39 B	0.39 J
1 3/4 IN CHAIN	-	-	-	-	-	-	-	20.00 J	20.00 J
1 3/4 IN DETACHABLE LINK	-	-	-	-	-	-	-	0.39 B	0.39 J
1 3/4 IN SWIVEL SHOT	25.00 J	25.00 J	25.00 J	25.00 J	25.00 J	25.00 J	25.00 J	25.00 J	25.00 J
1 3/4 IN DETACHABLE LINK	0.39 B	0.39 B	0.39 B	0.39 J	0.39 J	0.39 J	0.39 J	0.39 B	0.39 J
1 3/4 IN CHAIN	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J	90.00 J
2 IN DETACHABLE LINK	0.47 B	0.47 B	0.47 B	0.47 J	0.47 B	0.47 B	0.47 B	0.47 B	0.47 B
2 IN DIELOK - 3 LINKS	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
1 3/4 IN ANCHOR JOINING LINK	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C	0.86 C
2 1/4 IN SHACKLE	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
ANCHOR WEIGHT – #	9000	9000	9000	9000	9000	9000	9000	9000	9000
RISER LENGTH – FT	11			37			38		
GROUND LEG LENGTH – FT	547	547	547	547	547	547	547	547	547
MLLW DEPTH – FT	36			86			77		

C E. V. CAMP STEEL WORKS
B BALDT ANCHOR, CHAIN, AND FORGE COMPANY
J JAPANESE

The height of the ground ring above bottom can be determined roughly by subtracting the total of riser length and depth of buoy padeye (5 feet) from the mean lower low waterline depth and adding the tidal height. At low water, this height ranges from 20 feet for mooring #3 to 44 feet for mooring #4.

6.0 COSTS FOR PHASE II

The costs for the Phase II effort of the Indian Island Mooring installation are summarized below:

Refurbishment of 3 Buoys and Modification of 3 Anchors at PSNS -	$ 80,000.00
Army Reserve National Guard Travel/Per Diem/Spare Parts --------	22,000.00
Refurbishment of Army Crane at PSNS --------------------------	20,000.00
Chain Connecting Hardware from Baldt via CBC Davisville, RI ----	17,000.00
YD Services from PSNS ---	16,000.00
Completion Report ---	14,000.00
UCT-TWO ---	7,500.00
Replacement of Dynamometer ------------------------------------	5,000.00
Replacement of Broken Towline ---------------------------------	3,400.00
Repair of Broken Army Crane -----------------------------------	2,000.00
Replacement of Expended OCEI Equipment ------------------------	2,000.00
FPO-1 FY82 Labor/Travel ---------------------------------------	9,000.00
FPO-1 FY83 Labor/Travel ---------------------------------------	37,000.00
FPO-1 FY84 Labor --	5,000.00
Total	$240,500.00

This total cost can be compared with the original estimate. Initially, this was $235,000 but was increased by $45,000 to cover repair costs on Mooring #1 to a new estimate of $280,000.00, using the resources that were available for the actual work on the project.

Had a contractor been employed to perform these services or had only Navy assets been utilized for the installation, the estimated cost was $385,000.00. This demonstrates the obvious advantages which accrued in the utilization of the equipment and services of the Army Reserve National Guard.

7.0 LESSONS LEARNED

Although the Phase II mooring installation off Indian Island was to some extent a repeat performance of the Phase I operation in 1978, and although more time was available for detailed planning of the 1983 operations, there were still many lessons learned during Phase II that are applicable in similar future mooring installations and in other ocean construction projects.

NAVIGATION AND MARKER BUOY PLACEMENT

The use of the Mini-Ranger for close-in operations is somewhat limited by interference of surrounding land masses and reflections that distort the signal. This is particularly true when employing range-range navigation techniques from multiple transponder stations. More accurate results can be obtained by using a single station with a transit to determine bearing and a Mini-Ranger to determine distance. Because the accuracy of range-range navigation off Indian Island proved questionable, it was found that using transits to obtain bearings from two stations was the most reliable solution despite the more complex calculations involved using this method of navigation.

A back-up means of navigation should always be available on site. If the Mini-Ranger is the primary means, transits also should be on hand and if transits are the primary means then some distance measuring system should be available. Furthermore, all field engineers should be trained in the use of all surveying or location techniques and equipment. This should be routinely included in PDC training.

The instant location of the mooring installations, marker buoys, and pull test results could be improved if quality protractors, coordinate maps, and plotting boards for each transit location were provided. Better placement location accuracy could be achieved with these tools.

With regard to marker buoy placement, all marker floats should be numbered or otherwise identified, especially when using transits. Both range/bearing and anchor location markers are useful. Pre-measured and pre-tied marker float lines, using uniform lengths wherever possible, should be employed. Bungee cord sections should be tied at the top of each line so that the buoys can be recovered by pulling directly on non-elastic line.

MOORING INSTALLATION OPERATIONS

The use of a Finger Eater or a similar device is strongly recommended for future operations. It permits safe transfer of loads and a controlled lowering rate without the hazards of free-running chains. Although some time is lost in getting chain in and out of the device, the advantages far outweigh the disadvantages.

The important lesson learned from the failure of the crane on the Army BD was that a side pull on the crane hook should be avoided at all costs. If a sheave hanging from the hook is used with the line running through it attached to the crane barge deck, the other end of the line should be subjected to an equal side force. Observing along the main axis of the boom, the line through the sheave should form equal angles with the vertical on either side of the boom. Furthermore, it should be remembered that, although this technique doubles the length of line that can be lowered or raised, it also doubles the load on the crane hook.

A small watch circle is easier to obtain in the field by first assuring that the legs are taut along the bottom rather than by additional shortening of the riser. To obtain a taut, 3-leg mooring:

- Lay the first two legs as close to their planned location as possible.
- Pull on the mooring buoy to straighten out the first two legs prior to laying the third.
- Lay the third leg under moderate tension and then pull it tight before dropping anchor.

Pulling either on an anchor leg or on a buoy in a straight line from the side of the crane barge is difficult because the towline load tends to rotate the crane barge. Stability of route is far easier to maintain when the towline extends aft from the stern of a tug.

Having two YCs available for use as storage barges is advantageous from the time standpoint because:

- A complete mooring can be installed in a single trip to the mooring site.
- The second YC can be loaded and pre-rigged using a land crane without delaying construction operations.

PULL TEST TECHNIQUES

When conducting pull tests, every effort should be made to control the tug so as to maintain a steady pull. However, because occasional surges cannot be avoided, it is prudent to use a high safety factor when selecting towlines and components.

For safety reasons it is essential that test personnel stand well clear of the towline when it is under tension and that the dynamometer can be read from a safe distance. For these reasons, the dynamometer should be rigged so that it will not rotate away from the observers when the load is applied.

Large needle oscillations in the dynamometer make reading difficult. These occur for several minutes after a loading in a new direction is applied and as the tug RPM is adjusted for the desired pull. A technique that can be used to ameliorate this problem is to work up to the desirable towrope pull and to maintain this same pull throughout the tests without changing RPM. This can be accomplished as follows:

- Run the propeller up to an RPM that applies the desired load in any selected initial direction while using the tug rudder to maintain a constant heading.
- Take location readings on the mooring buoy.
- Alter the rudder angle (5°-10°) to cause the tug to sidle to a new heading and then ease off on the rudder to maintain that heading. (Note that right rudder will generate a sidle to port and left rudder will generate sidle to starboard.)
- Take location readings on the mooring buoy.
- Repeat the above until the tug has rotated through full circle.

Using this technique a reasonably steady pull will be maintained throughout the entire test which can be adjusted as necessary by slight changes in tug RPM. It will be found that this technique will result in more constant watch circle.

8.0 RECOMMENDATIONS

In the development of as-built information for this report, it became clear that Mooring Buoy #3 had been positioned approximately 50 feet closer to the mine shop, Building 189, than was intended. When the watch circle of the stern of an ammunition barge swinging about this mooring is calculated, it is found that the watch circle overlaps the 2350-foot ESQD radius from the mine shop. Because of this, it is recommended that the allowable storage capacity of barges using Mooring #3 be reduced from 150 kilopounds of ammunition to 125 kilopounds. It is also recommended that an accurate survey of the mine shop be performed.

A mooring buoy available on site at Indian Island was used to replace Buoy #1 because of the deteriorated condition of the buoy installed in 1978. It is recommended that Buoy #2 and Buoy #6, also installed in 1978, be replaced with refurbished buoys and that all three of the removed mooring buoys be restored to a usable condition in FY 84 or FY 85. A routine inspection and maintenance cycle should be established for these six moorings.

Future maintenance of the six Indian Island moorings requires the employment of special techniques if precise placement and restricted watch circle specifications are to be complied with throughout the life of the moorings. Buoy substitution may be accomplished using the standard technique of disconnecting the riser just below the buoy. However, this must be done at a low tide and the lifting of the riser must be held at a minimun or the anchors may be dragged and the watch circles enlarged. It is recommended that replacement of chains not be attempted without first consulting CHESNAVFACENGCOM.

9.0 ACKNOWLEDGMENTS

The team that carried out Phase II of the Indian Island Mooring Project comprised representatives of several different organizations, all of whom made a significant contribution to the success of the project. Some of those who contributed are listed below.

The CHESNAVFACENGCOM participants were Andrew Kurtz-Program Manager, Lawrence Mendlow-Project Manager and, Ted Jones-Project Engineer. On-site assistance was provided by Margo Walter, Craig Pennington, and LCDR Randall Bushey, USNR who was assigned to CHESNAVFACENGCOM on temporary training duty.

Liaison with the Puget Sound Naval Shipyard was provided by Bruce Van Woudenburg and Elmer Slagel of the Public Works Office, Code 422. The on-site rigger foreman was Ron Anderson who, along with the five other wharfbuilders from Shop 07 listed below, handled all of the anchor, chain and buoy installation work. They were assisted by the listed YD crane operator and welders.

Keith Ellis	Crane Operator, Shop 02
Ron Antonson	Roger Lazar
Sam Oleson	Welders, Shop 06
Jim Bernier	Bob Burbach
Gus Fender	Lloyd Geiser

Liaison with the 144th Transportation Battalion, Washington State Army Reserve National Guard was provided by 1LT Mosebach of that organization. On-site supervisors were CW4 Richard Bishop, CW4 Frederick Clifton, CW4 Harold Feaster, and CW4 Douglas Miller. Along with the other members of the Battalion listed below, they handled the two Army tugs and the BD crane barge.

SP5 Gregory Archbold	SSG Melroy Medhus
SSG Harry Borner	SP5 George Mierzwak
SP5 Robert Bourne	SP4 Kevin Mosley
WO1 Norman Carlson	SP5 Dale Parsons
SSG Charles Davis	CW2 Francis Poechhacker
CW3 Vernon Ellison	SSG Robert St. Clair
SSG Newell Hinote	SP4 William Smith
SP5 John Martin	SP6 Richard Taylor
SSG John McCoy	SSG Cecil Wiswell

The Underwater Construction Team Two divers who participated in the construction operations of the Phase II effort were:

William Johnson BU2/DV, POIC

Steven Wendt UT1/DV   Steve Sako EO3/DV

Dino Ciccone EA2/DV   Jorge Torrens EA3/DV

A total of 18 dives were made at an average depth of 73.3 feet totalling 5 hours, 55 minutes of bottom time. In addition, these divers ran the dive boat and placed and retrieved markers and floats throughout the operation as well as fulfilling other functions essential to the success of the mooring installation.

REFERENCES

[1] Indian Island Moorings Project Completion Report, FPO-1-79(9), October 1979.

[2] WESTNAVFACENGCOM letter 102.2, 28 April 1982 to CHESNAVFACENGCOM.

[3] Indian Island Fleet Moorings Underwater Inspection Report, FPO-1-83(2), April 1983.

[4] Indian Island Bottom Probe Report, Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, 4 January 1983.

[5] Indian Island Moorings Project Execution Plan, Volume I, FPO-1-79(9), September 1979

[6] Design Manual Harbor and Coastal Facilities (Including Change 1), NAVFAC DM-26, July 1968.

[7] CHESNAVFACENGCOM letter FPO-1FP2 of 3 June 1982 to Commanding Officer, Western Division, Naval Facilities Engineering Command.

[8] CHESNAVFACENGCOM Washington, DC message 231406Z Dec 82 to NAVUSEAWARENGSTA Det Indian Island WA.

[9] NAVUSEAWARENGSTA Det Indian Island WA message 071720 Jan 83 to CHESNAVFACENGCOM.

[10] CHESNAVFACENGCOM letter FPO-1C5 of 13 January 1983 to Commander, 144th Transportation Battalion, Tacoma, WA.

[11] 144th Transportation Battalion, LT Mosebach letter to CHESNAVFACENGCOM, Lawrence Mendlow of 22 May 1983.

[12] UCT-TWO message 242131Z Jan 83 to CHESNAVFACENGCOM.

[13] CHESNAVFACENGCOM Washington DC message 042030Z Feb 83 to COMCBPAC, Pearl Harbor.

[14] CHESNAVFACENGCOM letter FPO-1C5 of 25 March 1983 to Puget Sound Naval Shipyard.

[15] WESTNAVFACENGCOM, Work Request N62477-83-WR-00315, 17 May 1983 to Puget Sound Naval Shipyard.

[16] Indian Island Moorings, Phase II, Project Execution Plan, 22 July 1983, issued by CHESNAVFACENGCOM.

APPENDIX A

DESIGN OF MOORINGS WITH RESTRICTED WATCH CIRCLES

A DESIGN PROCEDURE FOR MOORINGS WITH RESTRICTED WATCH CIRCLES

by Thomas J. O'Boyle and Theodore P. Jones

Ocean Engineering and Construction Project Office
Chesapeake Division, Naval Facilities Engineering Command

ABSTRACT

This paper demonstrates a rational process for the design of moorings which require restricted watch circles. A systematic approach relating buoy deflection, water depth, anchor drag, leg pretension and other physical parameters is presented. The result is a pretensioned mooring which meets the performance requirements of a reduced watch circle and allows for the unknown anchor drag distances which arise from the geotechnical uncertainties of the site.

This approach has been successfully used by the Navy to design and install moorings for ammunition barges in Puget Sound, WA. It is not covered in standard Navy mooring design manuals, nor is it detailed in other port facilities design texts. Previous methods have not addressed the relationship between anchor drag and pretension forces. This method is an invaluable aid to the designer of a restricted watch circle mooring since it can easily be coded for a hand held calculator or a computer.

1. INTRODUCTION

The Officer in Charge of Construction, Naval Facilities Engineering Command, TRIDENT (OICC, TRIDENT) was tasked to provide three fleet moorings on the west side of Indian Island, Puget Sound, Washington. These moorings were Phase I of a total of six moorings to be installed at the Naval Undersea Warfare Engineering Station (NUWES), for securing YC and YFN ammunition barges. Due to unusual site characteristics and the tight positioning constraints of the Explosive Safety Quantity Distances (ESQD) it was imperative that the moorings be implanted in precise locations and that the mooring circles swept by the anchored barges be of minimal dimensions. See Figure 1.

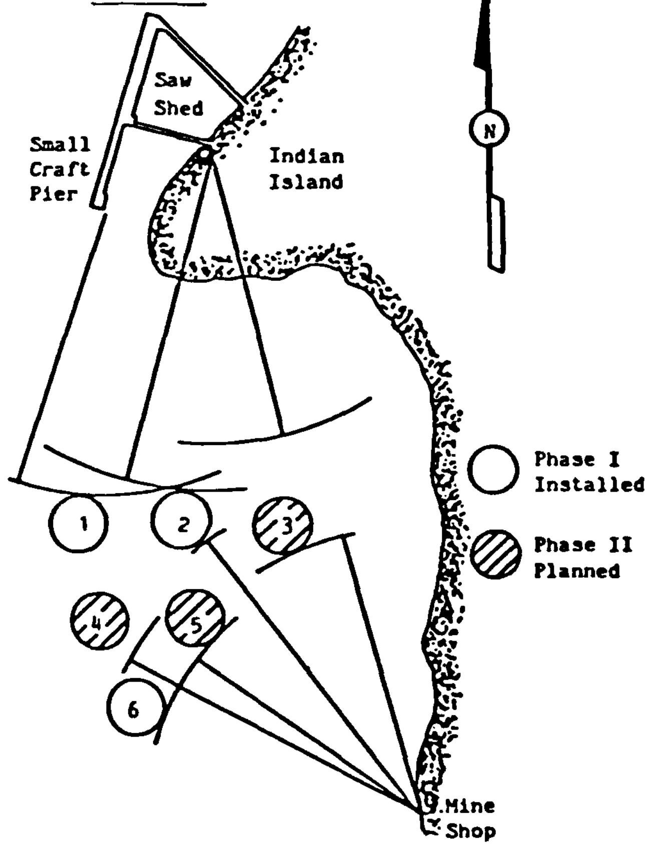


Figure 1

In June 1978, OICC TRIDENT requested that the Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command (CHESNAVFACENGCOM, FPO-1) perform a design review and determine the installation options for the first three moorings (Phase I). The remaining three moorings were to be designed in FY82 and installed in FY83. The moorings were designed to be permanent installations and hold the barges in a 100 mph wind with a nominal 2 knot current resulting in a 12 kip design load. The mean low water depths at the Phase I mooring locations varied slightly around 90 feet and the available bottom data indicated approximately 90 feet of zero blow count material below the mud line.

Prior to requesting that FPO-1 perform a design review, OICC TRIDENT procured the mooring materials based on the available information (90 feet of water plus 90 feet of zero blow count material).

In brief, the problem was to design a mooring for 90 feet of water using only the material already procured that could be accurately and cost effectively installed and, when under full design load, would have a buoy watch circle of 50 feet or less.

2. PHASE I

We wanted the final design for Phase I to remain as close as possible to a standard fleet mooring design, such as found in the Navy's Design Manual, NAVFAC DM-26 (July 1968). See Reference 1. All the Naval Public Works Centers (PWC) that install and service the existing fleet moorings use DM-26 as their guide. The PWC riggers are familiar with the configurations and connections of the standard mooring types. Also, the installation procedure would be familiar to PWC deck personnel and could be accomplished using Government assets. The installation would be safer than if a unique design was used. The main disadvantage of using the standard design for this installation was the large watch circle that is associated with a long riser. This large watch circle would be in excess of the allowable 50 foot maximum. The mooring configuration options we considered were: (a) a two point mooring; (b) a telephone-type mooring; (c) a free-swinging, shortened riser mooring. The two point (bow-stern) mooring would restrict the barge movement the greatest, but would require the procurement of more material. The telephone-type mooring brings all the anchor legs up to the buoy. This arrangement reduces the watch circle efficiently, but in this water depth, results in excessive weight in the water column. The buoys available on island were not large enough to support this much weight. The free-swinging mooring configuration was choosen as the best option.

A standard free-swinging riser-type mooring would have a buoy watch circle greater than 70 feet in this water depth. We had to modify this configuration to reduce the watch circle and keep the vertical load on the buoy low enough to maintain at least 18 inches of freeboard under a no load condition. We decided to achieve this by putting a pretension on each leg at the ground ring. See Figure 2. This pretension would be generated by lifting the ground ring a distance from its standard position near the bottom, thus creating a catenary in each leg.

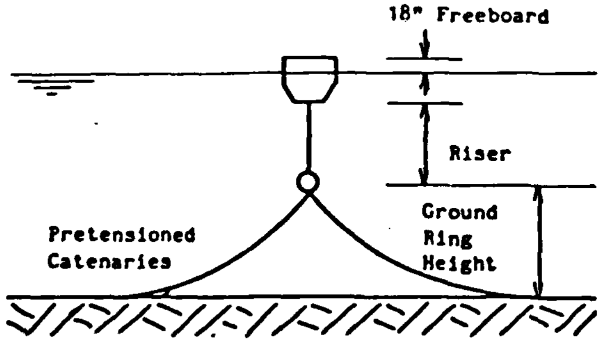


Figure 2

To aid in the numerous calculations, we used a programmable TI-59 calculator for Phase I. Because the programs written on the TI-59 could only handle one horizontal force applied to a catenary at a time, several preliminary loads had to be calculated before the final catenary model could be used. This final model simulated the mooring as a single leg made up of the ground chain and riser. The pretension applied to the ground ring and the calculated environmental horizontal load on the buoy were combined and applied at the buoy only.

The first calculations determined the vertical force needed to lift one end of a ground leg. We made the following assumptions:

1. the projected horizontal distances from the anchor to the ground ring remained constant for each series of vertical forces we applied,

2. the anchor did not move for each series of vertical forces,

3. the chain laid flat on a level bottom,

4. the chain started out straight and tight from the anchor to the ground ring,

5. the chain did not sink below the mud line, and

6. all the load was applied to a single leg.

To account for the unknown anchor drag distance in this zero blow count material, we shortened the projected horizontal catenary length in increments. We created a "synthetic riser" equal in length to the increment we removed. See Figure 3. The combined length of the synthetic riser and the chain on the bottom at zero load equalled the same constant for each anchor drag distance. Figure 4 shows the vertical load due to a single leg at equilibrium for a range of anchor drag distances and ground ring heights.

The vertical force calculation for a single leg was multiplied by 3 to determine the combined effect of all of the legs. We added a nominal riser weight to calculate the total vertical load on the buoy. This allowed us to remove many trivial cases from further consideration. The vertical force on the buoy had to be investigated for the full tidal range. We assumed the ground ring height would vary from +10 feet to -3 feet about its position at MLLW. For example, if the ground ring was 30 feet off the bottom at MLLW, the vertical load on the buoy was calculated for a ground ring height of 40 feet to check for overloading at high tide.

The relationship between the horizontal pretension force at the ground ring and the ground ring height for various anchor drag distances is given in Figure 5. These values are crucial in the final deflection model for the system.

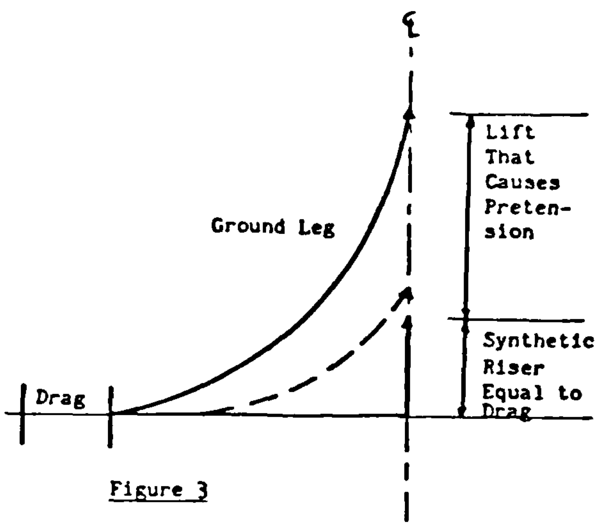


Figure 3

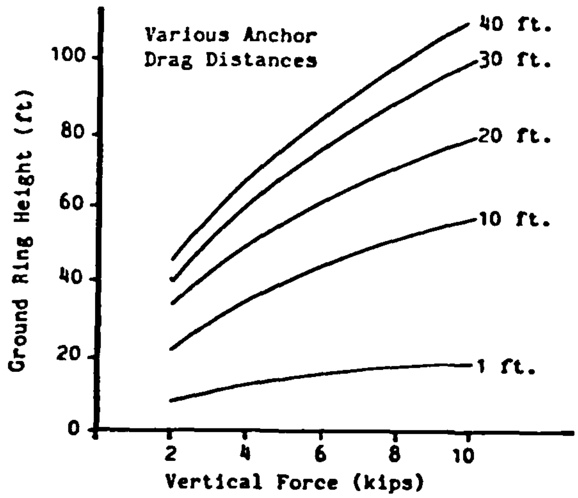


Figure 4

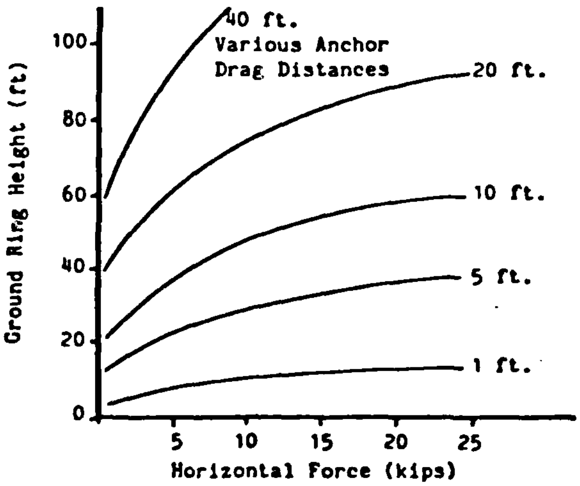


Figure 5

As mentioned previously, the TI-59 calculator can handle only one horizontal force applied to the catenary at a time. The model we used combined the pretension load on the ground ring and the horizontal load on the buoy and applied this load to the catenary at the water's surface. We checked the effect on the accuracy of the deflection calculation due to the combination of the two applied loads as follows. First, the deflection of a catenary formed by only the chain from ground ring to anchor was calculated for a horizontal force equal to the pretension plus surface horizontal forces for a water depth equal to the ground ring height. Second, the catenary was modified to include the riser from ground ring to surface, the same load was applied at the surface and the deflection of the ground ring was determined. These two deflections were approximately the same. This method resulted in a conservative watch circle estimate because the weight of the suspended chain from the other two legs was neglected. This weight would tend to reduce the watch circle.

Using the above model, we calculated the mooring's displacement from its no load position for a range of buoy loads. We plotted the results of these calculations on two sets of curves. The first curves showed Horizontal Displacement versus Horizontal Force. The horizontal force plotted was only the force at the buoy, not the combined force used for the displacement calculations. The second set showed Horizontal Displacement versus Total Vertical Force on Buoy. We used these curves to decrease the number of acceptable candidates by illustrating which configurations would result in vertically overloading the buoy at full deflection. This was not the same requirement as the 18 inch freeboard minimum at no load.

We then combined the information from the above curves into a set of final design curves. For each reasonable ground ring height, we plotted Anchor Drag versus Horizontal Displacement for various water depths and the associated riser lengths. The final design curves illustrated the critical anchor drag distances where: (a) the ground chain became slack below the ground ring; (b) there was excessive vertical force on the buoy, and; (c) there was excessive horizontal deflection of the buoy. The best ground ring height and riser length could then be chosen based upon the maximum anchor for all tidal depths.

During the design phase of this project, a detailed site survey was conducted of the mooring area, and the bathymetry confirmed a flat bottom. The subbottom profiles indicated the same type of material was present at all the mooring locations, but could not give any indication of the soil strength. Several Vibracores were taken in the area and showed a greenish gray organic material. The only indication of soil strength was obtained during an anchor pull test; the anchor remained on the upper layer of the mud after free-falling through the water column. A line secured to the crown measured the same as the water depth. These field findings strengthened our basic design assumptions and ensured an accurate design.

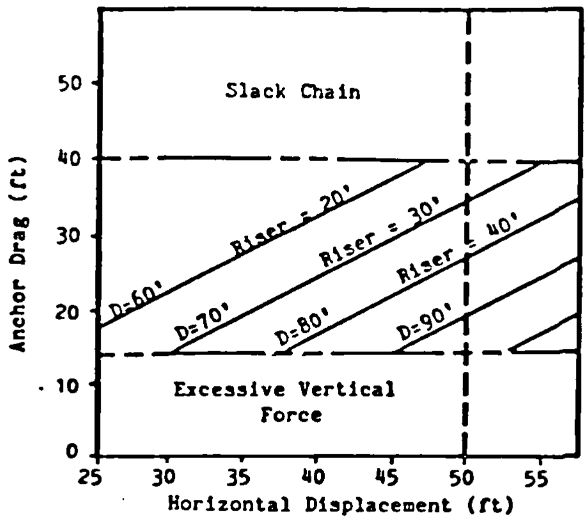


Figure 6

To avoid problems during installation, we kept the design of all three moorings identical. The design called for a three leg riser type mooring. Each ground leg was 430 feet long and was spaced 120° apart horizontally. Each riser was 35 feet long, placing the ground ring 40 feet below the surface. This constant riser length simplified the rigging. We calculated that each mooring would have a watch circle within the 50 foot maximum. The design allowed the following anchor drag tolerances: (a) each anchor would slip at least 15 feet, thus avoiding an excess vertical force on the buoy; (b) each anchor could slip up to approximately 30 feet and the mooring would still have less than a 50 foot watch circle.

The installation method was developed simultaneously with the design to ensure that the installation was feasible and that the assumptions made in the design would not be violated. The following scenario was used to install these moorings. Each buoy was fitted with a 45 foot section of chain that could be removed and a 35 foot riser which were attached to the ground ring. Each leg was laid out on the bottom from the ground ring toward a pre-positioned marker buoy. Each anchor's flukes were welded fully open and control lowered using a crown line so the flukes were pointed down. After all three legs of one mooring were installed, each anchor and chain was pulled radially outward using the crown line. This ensured that the chain was straight and tight. After this pull was accomplished, the buoy was lifted up high enough to allow the 35 foot riser to be secured to the deck and then the 45 foot piece of chain was removed. During the lifting operation the load was measured on a dynamometer secured between the buoy and the crane's hook. Using a graph of the Ground Ring Height versus Total Vertical Force, the approximate average anchor slip was determined. Then with this approximate value of anchor slip, the appropriate Anchor Drag versus Horizontal Displacement curve was used to get an approximate watch circle. This field prediction of the watch circle size was made by the engineer on site to see if it would be necessary to reset the anchors and try again. Each mooring's predicted watch circle fell below 50 feet and no anchor resetting was needed. The final step in the installation was to lower the buoy back into the water with the 45 foot chain section removed.

Unlike all standard Navy fleet moorings, these unique moorings were put through an acceptance test. A tug was secured to each buoy and a dynamometer measured the load applied in the line. The load was brought up to the design load and with this load held constant, the tug pulled approximately toward each anchor. The buoy displacement was noted using transits. The result was an average watch circle of 35 feet.

3. PHASE II

The same site characteristics and positioning constraints placed on the first three moorings held for these. As seen in Figure 1, these remaining moorings were bounded by the installed three. Also, the materials for Phase II were procured and on site. The 50 foot maximum watch circle at the same design load was still the main design criteria.

Phase II differed from Phase I in that the hardware was a smaller size, the placement of these three was more restricted due to the previously installed moorings and the number 3 mooring was to be installed on the side of a sloping bottom. Despite these differences the same concept was chosen.

For Phase II the TI-59 calculator was replaced by a catenary mooring program written to our specification by Presearch Inc. See Reference 2. The program is coded for a TEKTRONIX 4081 interactive graphic terminal in FORTRAN. This program has the graphic capabilities of displaying both an elevation view and a load-deflection curve for a mooring leg. The leg can have up to three different materials and two sinkers. Our program is flexible and can be used to analyze a catenary with a single leg or a compound leg using a spider plate or equalizer. Also, the program can do the analysis of a mooring on an inclined bottom. This program made it possible to drastically reduce the time required to perform the iterative calculations.

The material procured for Phase II included 9,000 pound Navy stockless anchors with stabilizers. The behavior of this particular anchor was known because the Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California had performed several anchor holding experiments at Indian Island. See reference 3. This exact anchor type was one of the types used by NCEL. The data from these pull tests was used to better predict the anchor drag distances and anchor holding capacities.

Moorings number 4 and 5 were analyzed using the same procedure as in Phase I. The unknown anchor drag distance resulting from lifting the ground ring made this parametric study necessary. Like-

wise, a parametric study was done for mooring number 3 but, because of the sloping bottom, each leg had to be investigated separately.

In November 1982, we conducted a bottom investigation at mooring site number 3. This investigation consisted of a team of divers swimming down the slope and trying to push a rod into the bottom at predetermined locations. The maximum penetration was approximately one foot. A grab sample from below the loose mud revealed a sandy silt bottom. Two of the mooring's three anchors will be placed in this soil and the third anchor will be in mud.

The final design for all three remaining moorings followed a similar procedure as before. Special consideration was given to the effect of the different bottom soils and slope on the movement of mooring number 3's anchors. The fluke angles will be set to sand on two of the three anchors for mooring number 3.

At this time it is anticipated that we will use a similar installation scenario as in Phase I. This has not been finalized and depends on vessel availability.

4. CONCLUSION

The Navy's successful installation and acceptance test of the three moorings in Phase I proves this procedure of shortening the riser to reduce the watch circle to be effective. The installation procedure is a critical factor to consider to ensure the results are as designed. This method also results in accurate positioning of the mooring.

The design procedure can easily be accomplished with a hand held calculator such as the TI-59. However, a computer aided mooring design program such as our's saves considerable time and effort during the iterative calculations.

5. REFERENCES

1. Naval Facilities Engineering Command, Harbor And Coastal Facilities Design Manual, NAVFAC DM-26, July 1968, Chapters 6 and 7.

2. Presearch Incorporated, Fleet Mooring Leg Design Program Documentation, Vol. 2, User Documentation, FPO-1-82(33), performed for Ocean Engineering and Construction Project Office, Chesapeake Division, Naval Facilities Engineering Command, under contract N62477-81-C-0025, December 1982.

3. Taylor, R.J., Conventional Anchor Test Results At San Diego and Indian Island, Technical Note 1581, Civil Engineering Laboratory, Naval Construction Battalion Center, July 1980, pg. 151.

APPENDIX B

PROJECT LOGS DURING 1983 BY SUBJECT:

- O PREPARATION AND PRE-RIGGING
- O DIVER INSPECTION
- O NAVIGATION AND MARKER BUOYS
- O CONSTRUCTION OPERATIONS

PREPARATION AND PRE-RIGGING

16 Aug: *1053* - Arranged to have Japanese chain at PWC moved to ammunition pier.

1200 - Verified OCEI shipment at Bldg 77.

1220 - Inspected other 2 1/4" and 1 1/2" chain available if needed.

1245 - Examined Baldt links on ammunition pier and approved shipment.

1300 - At ammunition pier, viewed barge that had arrived from Puget Sound Naval Shipyard. Material aboard included refurbished buoys, 25000# anchors, and rigging hardware.

1330 - Called UCT-TWO from Public Works to ascertain that Mini-Ranger System (MRSIII) was in Bangor.

1400 - Inspected Japanese chain and 9000# anchors in storage area.

17 Aug: *1000* - At Puget Sound Naval Shipyard, met foreman rigger-Ron Anderson - and crane operator - Charles Davis. Confirmed with them the shipping of material and planned working hours.

1300 - Went to WMMC in Tacoma, met with Fred Clifton, and viewed tugs available.

1345 - Moved over to National Guard Armory and met personnel who might be involved in project.

18 Aug: *0430* - At PSNS to witness test of BD. Test delayed; left at 0930.

19 Aug: *0900* - Went to ammunition pier to witness riggers welding anchor shackles and wedges and adding short pieces of die-lock chain (2") to anchors, 3 links each. Observed loading of one barge with three 9000# anchors and 18 shots of chain for installation of Buoy #5.

2030 - Met LCDR Bushey at airport.

20 Aug: *0900* - Transported OCEI equipment to Explosive Ordnance Disposal (EOD); filled pumpkin floats; charged radio batteries. Moved chain around with forklift. Welders worked on wedges with an average of 1.5 hrs/wedge.

1230 - Found 12 - 27-foot swivel shots on pier not reported in inventory. Cut 110-foot lengths of manilla ropes for marker floats.

2030 - Army arrived at pier.

21 Aug: *0800* - Moved tug and barges at pier and located diver's equipment but men had not yet appeared.

PREPARATION AND PRE-RIGGING (Cont'd.)

21 Aug: *1630* - Measured chain and found that there were numerous 45-foot shots.

22 Aug: *0715* - Held conferences with EOD and then with riggers and Army representatives at pier.

1310 - Obtained camera passes at Indian Island gate house.

25 Aug: *0800* - Completed partial packout of MRS III at pier and worked on pre-rigging of #1 and #4 mooring systems.

27 Aug: *1130* - Looked at spare peg top buoy with hawse pipe in storage area and decided to use it.

1600 - From pier, made telephone calls to locate a new dynamometer.

29 Aug: *0800* - Sent to Bremerton for a new dynamometer.

1600 - Made telephone calls to arrange for a YD. Processed remainder of the MRS III for shipping.

30 Aug: *0800* - Mr. R. L. Asher, FPO-1C, arrived together with Army officers to discuss best solution to crane problems.

1400 - 100-foot tug took Army BD to Bremerton, picked up Navy YD, and returned to Indian Island.

31 Aug: *0730* - New crane and tug arrived.

DIVER INSPECTION

23 Aug: *1837* - Inspecting Buoy #5. Crown lines go into mud on all anchors. The ground ring is three links below the mud line. Fifty feet of each leg is accessible with good bearing.

25 Aug: *0700* - Inspecting Buoy #4. No obstructions seen near anchor locations.

27 Aug: *0900* - Inspecting Buoy #4. Made dives on crown lines.

1300 - Inspecting Buoy #4. Examined catenaries of ground leg chains.

2 Sep: *0900* - Inspecting Buoy #3. Examined catenaries of ground leg chains.

3 Sep: *0900* - Inspecting Buoy #3. Made detailed examination of riser.

NAVIGATION AND MARKER BUOYS

16 Aug: *0945* - Made transit to Kala Point to confirm location of site point marker.

16 Aug: *1410* - Attempted to locate Cliff site point but could not get through thick brush.

1430 - Searched for Walan site point but failed to locate marker.

18 Aug: *1000* - Met with Tim Cleveland at NWES Keyport and obtained a Survey Control Manual.

1300 - Returned to Indian Island and obtained a machete and gloves.

1343 - Managed to locate Walan site point marker.

1430 - Hacked through underbrush in vicinity of Cliff site point and located marker.

20 Aug: *0930* - Went to Kala site point and showed marker to LCDR Bushey.

1100 - Returned to pier and measured 250 meter calibration range.

1230 - Returned to Cliff to improve access to site.

21 Aug: *0930* - At pier on Indian Island, calculated ranges from Cliff, Walan, Kala, and Crane.

1130 - Unpacked Mini-Ranger.

1200 - Set up batteries and calibrated Mini-Ranger.

1630 - Set up one receiver/transmitter and console aboard 45 foot tug.

22 Aug: *0750* - Set up reference station on Kala Point. The signal was satisfactory aboard the tug.

0950 - Set up reference station at Crane and this signal was satisfactory aboard the tug.

1050 - Returned to pier and placed marker buoys and clump on small tug.

1100 - Using 45 foot tug, placed markers for Buoy #5 but had difficulty with Mini-Ranger readings from Kala and Crane. The buoys were installed but the locations appeared unsatisfactory.

1330 - Set up transits at Cliff and Walan. Calculated ranges for Buoy #5 marker buoys.

1400 - Aboard dive boat. Repositioned Buoy #5 marker buoys.

1600 - Removed reference stations at Walan and Crane.

1700 - Calculated new angles based on moving Cliff 7 feet toward Walan to clear obstructions.

23 Aug: *0600* - Set up reference station at Kala Point.

0730 - Divers worked at clearing the access route to Cliff.

0830 - Aboard the 100 foot tug (LT). Tied the receiver/transmitter to the mast and transferred the Mini-Ranger console aboard.

23 Aug: *0900* - Removed the transits from Cliff and Walan because of bad visibility.

2200 - Calculated angles from new Cliff marker to new range marker positions. Decided to abandon the Mini-Ranger System (MRS III) and rely on transits for buoy location.

24 Aug: *1400* - Aboard the dive boat. Installed Buoy #4 marker buoys.

25 Aug: *0800* - At pier. Created new "true grid" chart.

1100 - Sighting from Cliff and Walan. Observed* the shortening of Buoy #5 riser. The buoy was 63 feet northwest of desired location.

1430 - Observed Buoy #5 pull tests and took final transit readings of Buoy #5 and the three crown line buoys.

26 Aug: *0800* - Monitoring construction operations for Buoy #4.

1700 - Installed Buoy #1 marker buoys.

27 Aug: *0830* - Installed peanut floats at anchor locations for Buoy #4.

0915 - Verified Buoy #1 marker buoy locations and observed anchor adjustment on Buoy #4.

1400 - Observed pull test on Buoy #4 which was a failure.

29 Aug: *0800* - Observed installation of Buoy #1.

1530 - Observed pull test on Buoy #4.

31 Aug: *0900* - Observed laying of third leg of Buoy #1 and pulling on anchor for leg C of Buoy #4.

1 Sep: *0900* - Observed riser shortening on Buoy #4.

1030 - Observed pull tests on Buoy #4.

2 Sep: *0900* - Observed installation of Buoy #3.

1600 - Observed pull tests on Buoy #1.

3 Sep: *0800* - Observed pull tests on Buoy #3.

---

*In this and the following operations, sights were taken with transits from Cliff and Walan on the objects being observed. In a few instances the dive boat was positioned at a particular marker float to clear up confusion.

CONSTRUCTION OPERATIONS

23 Aug: *0900* - Aboard crane barge. Modified "finger eater" to fit Army cleat.

0945 - Lead line depth indicated 36 feet where chart showed 50-60 feet.

1000 - First anchor (A) for Buoy #5 installed and crown buoy in position.

1130 - Applied hard pull with tug and barge to straighten out first leg of Buoy #5.

1240 - Buoy #5 in water.

1450 - Anchor for leg C of Buoy #5 in place.

1530 - Crown buoy for anchor C of Buoy #5 in position.

1600 - Returned to Buoy #5 for installation of last leg (leg B).

1745 - Leg B installed. Tug backed down to pull leg B taut.

1835 - Anchor for leg B of Buoy #5 in place.

1900 - Returned to pier.

24 Aug: *0900* - Recovered pumpkin floats from Buoy #5.

0915 - Crane barge underway to relocate Buoy #1.

0948 - Attached hook to Buoy #1.

1000 - Lifted Buoy #1 to get ground ring on crane barge deck. One leg of mooring slack with other two mooring legs taut. Recovered first leg with each shot being disconnected and put aboard storage barge. Leg B was marked with a yellow ribbon.

1200 - Raised anchor and cut off old rigging wire.

1225 - Buoy was raised to get to second leg which was cut off and the second leg (leg A) was recovered.

1430 - Raised second leg anchor. From the rigging arrangement it appeared that the anchor had been rigged upside down.

1450 - Again raised Buoy #1.

1500 - Cut off Buoy #1 riser.

1510 - Recovered third ground leg of Buoy #1, leg C.

1630 - Raised third anchor of Buoy #1.

1700 - Returned to pier.

1740 - Flashers were placed on various marker buoys of Buoy #5.

25 Aug: *1055* - Crane barge underway to Buoy #5.

1145 - Shortened riser of Buoy #5 by lifting buoy with big hook and removing links.

1200 - Returned crange barge to pier.

1300 - Rigged large tug for running pull tests.

25 Aug: *1430* - Headed for Buoy #5.

1505 - Proceeded to apply 12000# pull in six directions.

26 Aug: *0800* - Departed pier to install Buoy #4.

0910 - Lowered first anchor, leg A.

0940 - First crown buoy in place, leg A.

1030 - Divers removed three crown buoys from Buoy #5 mooring.

1048 - Shortened riser on Buoy #4.

1111 - Lowered Buoy #4 into water.

1130 - Second leg (C) throw-off removed from top of riser and brought on deck. Leg C anchor hooked up ready for lowering.

1325 - Leg C anchor down with crown line running through sheave. Crown buoy on deck.

1340 - Crown buoy lowered into water.

1415 - Picked up crown buoy to pull anchor due west but pennant broke.

1440 - Tried to pull on anchor again by lifting and pulling crown buoy. However, wire rope twisted excessively. Decided to lay leg B to see if buoy was off location. Conclusion was that it was only 15 feet off location and therefore satisfactory.

1500 - Headed back to Buoy #4 to pick up throw-off leg B.

1640 - Lowered anchor for leg B.

1700 - Anchor for leg B on bottom. Headed for pier.

27 Aug: *0845* - Returned to Buoy #4 and lifted leg C anchor.

0915 - Lowered anchor at pre-determined location.

0940 - Moved over to Buoy#4 to pull first two legs taut.

1000 - Attached to leg B crown buoy, picked up crown buoy, and pulled on chain until taut.

1030 - Lowered leg B anchor back to bottom and returned crown buoy to water.

1206 - Got underway to shorten riser on Buoy #4.

1237 - Lifted buoy from water and removed 45 feet from riser. Placed Buoy #4 back in water where it floated somewhat higher than Buoy #5 (8 inches lower than before riser removal).

1300 - Returned to pier with crane barge in tow and headed back out to Buoy #4 with tug alone to conduct pull test.

27 Aug: *1430* - Began pull but quickly exceeded strength of wire and destroyed dynamometer.

1500 - Returned to pier, concluding that casualty was due to high wind.

29 Aug: *0830* - Departed pier for Buoy #1.

0850 - On station and preparing first leg B, for deployment.

0900 - Connected first shot of chain and crown line with anchor hanging over side.

0955 - Lowered first anchor to bottom.

1010 - Crown buoy for first leg of Buoy #1 in water.

1050 - Rigged to install Buoy #1.

1145 - Buoy, riser, and two throw-off legs in water. Leg A stoppered off on deck and leg C tied to buoy.

1155 - Started laying second ground leg, leg A, of Buoy #1.

1320 - Pulled Buoy #1 northward 25 to 50 feet by pulling on leg.

1350 - Began lowering second anchor when crane casualty occurred.

1415 - Lowered anchor by topping down the crane boom and putting stress on wire rope. Burned through wire to drop anchor.

1430 - Returned to pier.

1500 - Headed out to Buoy #4 with tug equipped with new dynamometer to conduct pull test. A heavier (1 inch) pennant was used.

1540 - Conducted pull test on Buoy #4. All radii were too great.

1620 - Returned to pier.

30 Aug: No operations

31 Aug: *0930* - Departed pier for Buoy #1. Tug used to pull Buoy #1 in the direction of leg C. Pulled at 120 RPM for 3 minutes.

1000 - Returned to pier to fix problem on tug and then headed back out.

1130 - On station at Buoy #1 to connect to third leg, leg C, and then proceeded to lay leg C.

1300 - Pulled leg C tight. Connected anchor to crown line while trying to maintain position.

1428 - Crown buoy overboard.

1430 - Anchor on bottom. Leg C of Buoy #1 completed. Headed for Buoy #4.

31 Aug: *1450* - Extended riser of Buoy #4 by 45 feet previously removed.

1500 - Headed for crown buoy of third leg, leg C, and secured crown buoy to stern of tug. Pulled on crown line and broke nylon at 240 RPM.

1610 - Departed Buoy #4 for Buoy #1, leg C crown buoy. Secured to crown line and applied pull until movement was noted. Then applied a sustained pull but the net result was no significant movement of the crown buoy or Buoy #1.

1845 - Headed for pier.

1 Sep: *0740* - Left pier to shorten the riser on Buoy #4. Raised buoy, cut off 45 feet of riser, and reconnected buoy.

0900 - Lowered Buoy #4 back into water. Buoy freeboard was much improved.

0910 - Headed for Mooring Buoy #1 and to crown buoy of leg C. Lifted crown buoy but set back down due to high winds and small craft advisory.

0920 - Returned to pier.

0950 - Tied up YD and rigged large tug for pull test on Mooring Buoy #4.

1050 - Conducted pull test successfully.

1130 - Returned to pier.

2 Sep: *0815* - Crane barge underway for Mooring Buoy #3.

0853 - Placed anchor for leg A in water and moved YD into position for lowering.

0910 - Anchor on bottom. Started laying first leg, leg A.

1015 - Disconnected the end of the first shot of the second leg, leg B, from the top of Mooring Buoy #3, stoppered off the end of the chain, and lowered the buoy into the water.

1026 - Started laying the second leg, leg B.

1103 - Reached end of last shot of leg B, attached anchor to chain, and lowered anchor to bottom.

1124 - Back at Mooring Buoy #3 to pick up third leg, leg C; disconnected first shot of chain from top of buoy and brought it aboard crane barge.

1150 - Pulled on first shot of leg C to remove slack from legs A and B.

CONSTRUCTION OPERATIONS (Cont'd.)

2 Sep: *1202* - Started laying third leg, leg C.

1235 - Anchor and crown line connected to leg C. Began pulling westward to tighten legs.

1330 - Lowered leg C anchor to bottom.

1358 - Attached crown buoy, released crown line, and headed for Mooring Buoy #1.

1412 - At Mooring Buoy #1, the crown buoy for leg C was picked up, the anchor pulled to the prescribed location, and the crown buoy released.

1447 - Headed for Mooring Buoy #1 to shorten riser.

1456 - Buoy #1 lifted out of water, riser pulled clean, removable section taken out, and buoy reconnected to riser.

1522 - Lowered buoy into water and disconnected from crane.

1530 - Returned to pier.

1600 - Went out again to Mooring Buoy #1 site with 100' tug only to conduct pull test.

1620 - Rigged for pull test and conducted one set of 12 kip pulls and one set of 25 kip pulls.

1800 - Returned to pier.

3 Sep: *0750* - Left pier to shorten riser on Mooring Buoy #3.

0821 - Lifted buoy and removed 25-foot section. Then reconnected and lowered.

0850 - Sent diver down to inspect elevation of ground ring.

1002 - After report that ground ring was still on bottom, shortened riser by another 12 feet. Would have preferred 15-foot shortening but swivel location would not permit.

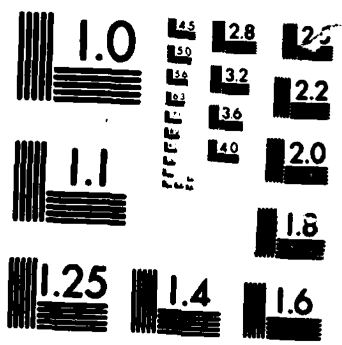
1014 - Tied crane barge to Mooring Buoy #5 to free tug for conducting pull test on Mooring Buoy #3.

1026 - Conducted pull test.

1107 - Disconnected tug, picked up crane barge, and returned to pier.

AD-A168 603 INDIAN ISLAND MOORING PROJECT PHASE II COMPLETION REPORT(U) TAGGART (ROBERT) INC FAIRFAX VA MAR 84 CHES/NAVFAC-FPO-1-84(2) 2/2

UNCLASSIFIED F/G 13/2 NL



MICROCOP CHART

APPENDIX C

CORRECTION OF BATHYMETRY CONTOURS FOR ERRORS IN 1978 BENCH MARK LOCATIONS

A bathymetric survey of the Indian Island mooring area was conducted in 1978 by Shannon & Wilson, Inc. of Fairbanks, Alaska. The results were reported to OICC TRIDENT in a letter report dated 18 January 1979. The navigation for this survey employed a Motorola Mini-Ranger III microwave positioning system using two shore-based transponder stations, one on Kala Point and the other on Indian Island (Walan). During the Phase I mooring installation, it was found that the Kala Point station used had been incorrectly identified and located. This resulted in an error in the locations for moorings #1, #2, and #6 and in the depth contours derived by Shannon & Wilson.

The mooring buoy locations were corrected in the Phase I completion report and the corrected locations were used in the Phase II planning. The depth contours, however, were not corrected and the distorted contours were used. This created a problem particularly in the location of mooring #3 which was implanted in an area where the bottom shoaled off close to the Indian Island shoreline.

For the purposes of this Phase II completion report, it was decided to correct insofar as possible the bathymetry in the mooring area. This correction has been limited to shifting the plotted depth contours laterally and rotating them a slight amount based upon the calculated relocation of three plotted points within the mooring area.

The Washington State Lambert North Zone Coordinates are used throughout to denote transponder locations and bathymetry relocation points. Coordinates are designated by X and Y where X is east and Y is north. Additionally:

w = range in feet measured from Walan and subscript denoting Walan

k = range in feet measured from Kala and subscript denoting Kala

ℓ = range in feet from Walan to Kala

p is subscript denoting presumed locations - wrong bench mark

a is subscript denoting actual locations - correct bench mark

The actual locations for the Walan and Kala transponders used in the 1978 survey are:

Walan -	$1,532,462 = X_w$	$397,070 = Y_w$
Kala transponder, actual -	$1,527,416 = X_a$	$391,865 = Y_a$

and the presumed location for the Kala transponder is:

Kala transponder, presumed - 1,527,584 = X_p 391,817 = Y_p

For existing bottom contours where the incorrect Kala location was used the following apply:

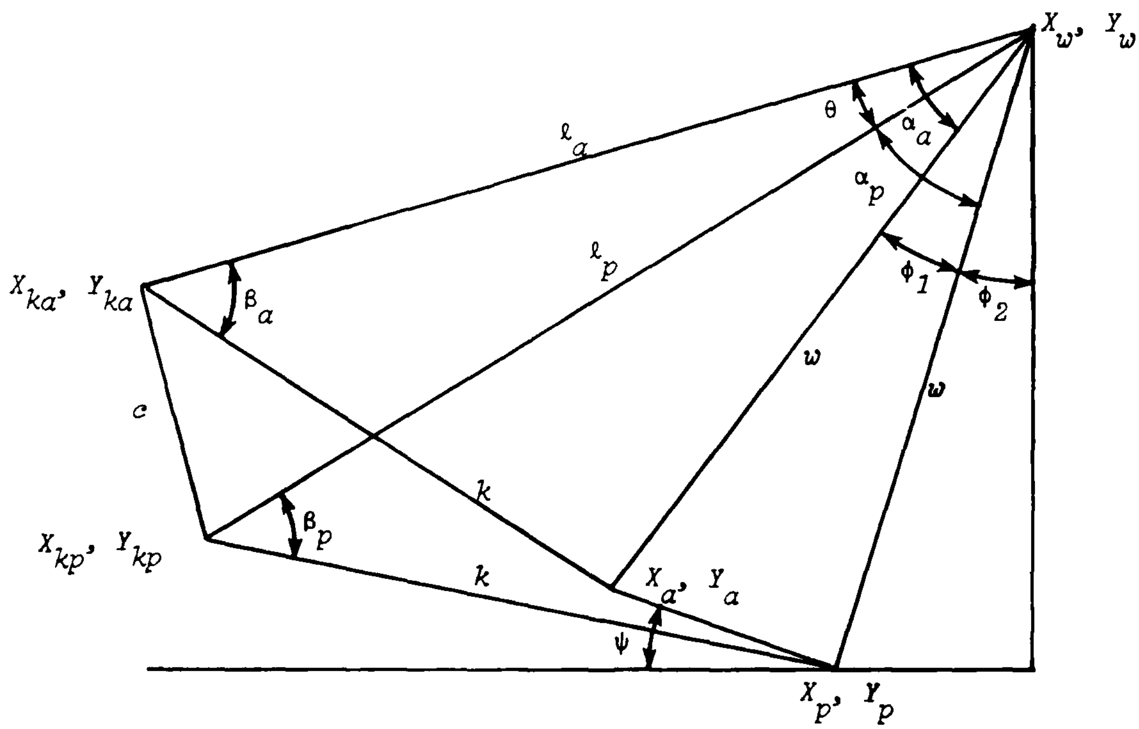
$$w^2 = (X_p - 1532462)^2 + (Y_p - 397070)^2$$

$$k^2 = (X_p - 1527584)^2 + (Y_p - 391817)^2$$

And for the correct plots using actual Walan and Kala transponder locations:

$$w^2 = (X_a - 1532462)^2 + (Y_a - 397070)^2$$

$$k^2 + (X_a - 1527416)^2 + (Y_a - 391865)^2$$



Referring now to the diagram above, which shows the Walan location (X_w, Y_w), the presumed Kala location (X_{kp}, Y_{kp}), and the actual Kala location (X_{ka}, Y_{ka}), we designate the following angular relationships:

$$\alpha = arc\ sin\ (\frac{k}{w}\ sin\beta)$$

$$\beta = arc\ cos\ (\frac{\ell^2 - w^2 + k^2}{2k\ell})$$

Also it can be calculated that:

$$\ell_p = 7169 \qquad \ell_a = 7249 \qquad c = 174.72$$

Additionally:

$$k^2 = \ell_a^2 + w^2 - 2w\ell_a \cos\alpha_a \qquad \alpha_a = \text{arc cos}\left(\frac{\ell_a^{\,2} + w^2 - k^2}{2w\ell_a}\right)$$

$$k^2 = \ell_p^2 + w^2 - 2w\ell_p \cos\alpha_p \qquad \alpha_p = \text{arc cos}\left(\frac{\ell_p^{\,2} + w^2 - k^2}{2w\ell_p}\right)$$

$$c^2 = \ell_a^2 + \ell_p^2 - 2\ell_a\ell_p \cos\theta \qquad \theta = \text{arc cos}\left(\frac{\ell_a^{\,2} + \ell_p^{\,2} - c^2}{2\ell_a\,\ell_p}\right)$$

$$d^2 = 2w^2\,(1 - \cos\phi_1) \qquad \phi_1 = \alpha_p + \theta - \alpha_a$$

$$d = w\,\sqrt{2\,(1 - \cos\phi_1)} \qquad \phi_2 = \text{arc sin}\left(\frac{X_w - X_p}{w}\right)$$

$$w \sin(\phi_1 + \phi_2) = X_w - X_a$$

$$X_a = X_w - w \sin(\phi_1 + \phi_2)$$

$$w \cos(\phi_1 + \phi_2) = Y_w - Y_a$$

$$Y_a = Y_w - w \cos(\phi_1 + \phi_2)$$

To recapitulate:

$$\alpha_p = \text{arc cos}\left(\frac{\ell_p^{\,2} + w^2 - k^2}{2w\ell_p}\right)$$

$$\alpha_a = \text{arc cos}\left(\frac{\ell_a^{\,2} + w^2 - k^2}{2w\ell_a}\right)$$

$$\phi_1 = \alpha_p - \alpha_a + 1.2346^\circ$$

$$\phi_2 = arc\ sin\ (\frac{X_w - X_p}{w})$$

$$X_a = X_w - w\ sin\ (\phi_1 + \phi_2)$$

$$Y_a = Y_w - w\ cos\ (\phi_1 + \phi_2)$$

$$d^2 = (X_a - X_p)^2 + (Y_a - Y_p)^2$$

$$\psi = arc\ sin\ (\frac{Y_a - Y_p}{d})$$

The three points selected for calculation are:

Presumed Point 1

$X_p = 1532000$ $w = 2121$ $\ell_p = 7169$

$Y_p = 395000$ $k = 5444$ $\ell_a = 7249$

$\alpha_p = 30.3021°$ $\phi_1 = 4.5812°$ $\phi_1 + \phi_2 = 17.1623°$

$\alpha_a = 26.9555°$ $\phi_2 = 12.5811°$

Actual Point 1

$X_a = 1531836$ $d = 170$ *West 164 ft*

$Y_a = 395043$ $\psi = 14.69°$ *North 43 ft*

Presumed Point 2

$X_p = 1532000$ $w = 4096$ $\ell_p = 7169$

$Y_p = 393000$ $k = 4572$ $\ell_a = 7249$

$\alpha_p = 36.4026°$ $\phi_1 = 2.2649°$ $\phi_1 + \phi_2 = 8.7412°$

$\alpha_a = 35.3723°$ $\phi_2 = 6.48°$

$X_a = 1531840$	$d = 161$	West 160 ft	
			Actual Point 2
$Y_a - 393022$	$\psi = 7.85°$	North 22 ft	

$X_p = 1533000$	$w = 3117$	$\ell_p = 7169$	
			Presumed Point 3
$Y_p = 394000$	$k = 5839$	$\ell_a = 7249$	

$\alpha_p = 52.8067°$	$\phi_1 = 2.6032°$	$\phi_1 + \phi_2 = 7.3359°$
$\alpha_a = 51.4381°$	$\phi_2 = 9.9391°$	

$X_a = 1532860$	$d = 142$	West 140 ft	
			Actual Point 3
$Y_a = 393979$	$\psi = 8.50°$	North -21 ft	

Using the west and north movements of the depth contours relative to the coordinates as derived above, the contours were then shifted to the west and rotated counterclockwise with respect to the coordinate grid to get the best fit possible to the relocated points. Although not exact, this treatment is expected to equal in accuracy the original contour plots. These revised contours have been used in all illustrations for this report except Figure 2-3.

END

DTIC

1-86